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ABSTRACT

This guide, which is one in the "Exploration" series of curriculum guides intended to assist junior high and middle school industrial educators in helping their students explore diverse industrial situations and technologies used in industry, deals with electricity and electronics. The following topics are covered in the individual lessons: the fundamentals of electricity (electricity as the flow of electrons and procedures for making and using a continuity tester); energy transducers (the purposes and operating principles of energy transducers and procedures for making and testing energy transducers); output transducers and control devices (the function of output transducers and control devices and steps in making and testing electrical circuits); series and parallel circuits (understanding how such circuits function and making and testing them); and the fundamentals of electronics (basic electronic devices and systems and making and analyzing an electronic alarm). The guide includes the rationale behind its development, hints to the teacher, lesson plans, student handout masters, teacher aids, a unit examination, and a list of references. The lesson plans include cross-referenced lists of objectives, lesson content, and learning activities. (MN)

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The Illinois
Plan for Industrial
Education

Illinois
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Education

Adult,
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ED296097

EXPLORING ELECTRICITY/ ELECTRONICS

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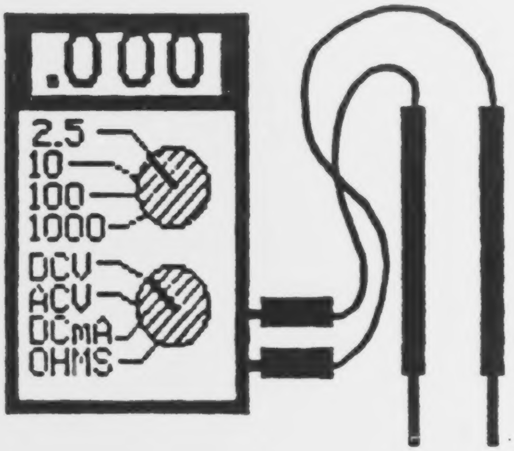
PACKET INCLUDES:

Rationale
Hints to the Teacher
Lesson Plans
Student Handout Masters
Teacher Aides
Unit Examination
References



ILLINOIS PLAN FOR INDUSTRIAL EDUCATION

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INTRODUCTION

"Exploring Electricity/Electonics" is one of a series of curriculum materials developed for junior high and middle school industrial educators. Listed below are the titles of the units in the series.

Communication
- Using the Language of Industry
- Exploring Computer Technology
- Exploring Photography
- Exploring Graphic Communication
- Exploring Electronic Communication

Energy Utilization
- Exploring Solar Energy
- Using Alternate Energy Sources
- Conserving Energy Sources
- Exploring Electricity/Electronics
- Exploring Mechanical and Fluid Systems

Impact of Industry and Technology
- Recycling Materials
- Limiting Pollution
- Exploring Careers in Industry and Technology
- Exploring Technology and the Future

Production
- Exploring Materials and Processes
- Exploring Construction Technology
- Research and Development
- Exploring Manufactured Systems
- Servicing Products

Transportation
- Exploring Land Transportation Systems
- Exploring Aviation Technology
- Exploring Water Transportation Systems
- Exploring Space Transportation Systems
- Exploring Materials Handling Systems

With the Exploration Series, industrial educators can lead their 7th and 8th grade students in exploring many industrial situations and technologies used in industry. In addition, this series can serve as a resource for teachers orienting 9th and 10th grade students to industrial technologies in communication, production, energy utilization and transportation. Each unit in the series includes a rationale, hints to the teacher, lesson plans, student handouts, teacher aids, a unit examination, and a list of references.

"Exploring Electricity/Electronics" and other units in the series are available on a cost recovery basis through the Curriculum Publications Clearinghouse, Western Illinois University, Horrabin Hall 46, Macomb, IL 61455.

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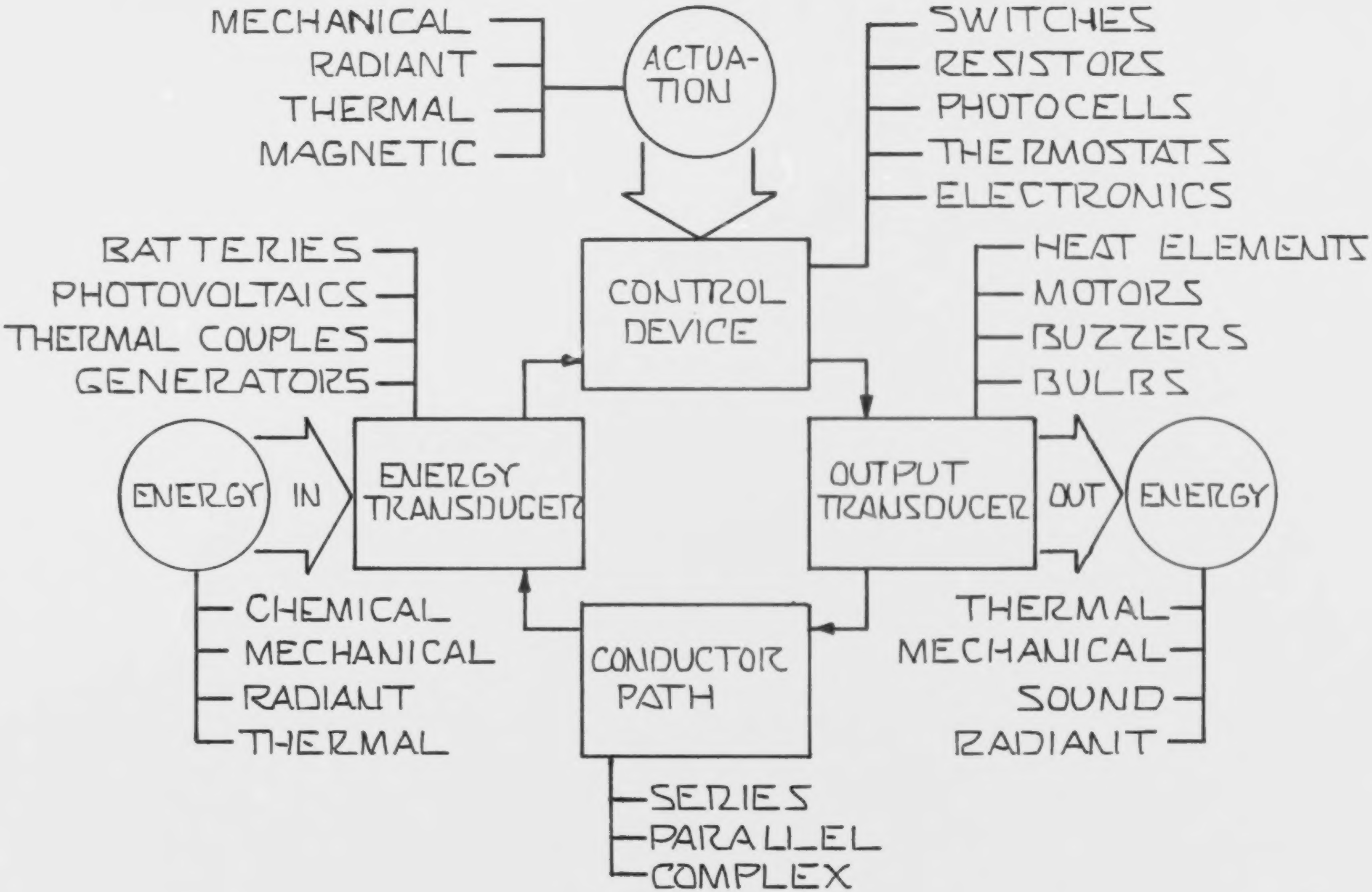
RATIONALE

Electricity/electronics has shaped, and will continue to shape the way we live. Many of the technological activities in manufacturing, transportation, agriculture, medicine, construction, communication, and energy rely heavily on electricity and electronics to improve our quality of life. Without electricity/electronics, we would not have telephones, radios, televisions, lights, or computers. Given the significance of these technologies in our culture, it is important that students develop a basic understanding of how electrical and electronic systems work.

During this unit, students will have an opportunity to learn about the energy transducers, output transducers, control devices, and conductor paths that make up an electrical system. While learning about electricity/electronics, students will be applying a variety of science and mathematic principles. In addition, this unit will provide a basic foundation for further studies in technology.


MECHANICAL
RADIANT
THERMAL
MAGNETIC
ACTUATION
SWITCHES
RESISTORS
PHOTOCELLS
THERMOSTATS
ELECTRONICS
BATTERIES
PHOTOVOLTAICS
THERMAL COUPLES
GENERATORS
CONTROL DEVICE
HEAT ELEMENTS
MOTORS
BUZZERS
BULBS
ENERGY
IN
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
OUT
ENERGY
CHEMICAL
MECHANICAL
RADIANT
THERMAL
CONDUCTOR PATH
THERMAL
MECHANICAL
SOUND
RADIANT
SERIES
PARALLEL
COMPLEX

HINTS TO THE TEACHER

1. This unit focuses on electricity/electronics as an energy utilization system. Using the concept of a circuit as a central theme, your students will explore the energy transducers, output transducers, control devices, and conductor paths that make up an electrical system. Emphasis has been placed on converting and controlling energy. As a result, very little attention has been given to static electricity, magnetism, and Ohm's Law. If you want to address these topics, they can easily be integrated into this unit.

2. This unit contains a minimum of fourteen lab activities. Each lab activity requires specific hardware. Prior to implementing this lesson, you will need to review each lab activity, identify the lab activities you want your students to perform, identify the tools, materials, and components you need to purchase, and prepare the lab activities. The electronics supplies can be purchased from any of the popular electronics vendors.

3. An effort has been made to minimize the need for soldering in the lab activities. The continuity tester and the burglar alarm projects use screws to make electrical connections. However, you will need to solder leads onto several of the components needed to make the burglar alarm. If you are going to make a lot of burglar alarms, you may want to ask students with soldering experience to help you put leads on components.

4. During the lab activities, your students will be building circuits by connecting components with jumper leads. To extend the life of electronic components, the authors highly recommend mounting each component on a fixture. Leads from each component can be wrapped around bolts and fastened with nuts. The bolts can serve as terminals. When polarity is important, the terminals can be labeled positive and negative.

5. During this unit, you will need to show students examples of energy transducers, output transducers, control devices, and conductor paths. Contact your local electronic service centers and related industries to help you collect electrical and electronic components.

6. An excellent way for students to prepare for the unit exam is to have them make, test, and exchange quiz boards. A description of and plans for a quiz board are provided in the Introduction to Electricity lesson.

7. To reduce the cost of implementing this unit, consider organizing the lab activities for Lessons 2, 3, and 4 into work stations. During each lesson, rotate groups of students from one work station to the next until they have completed all the lab activities.

8. Consider complementing your instruction with films and/or videotapes on electricity and electronics. Another way to complement your instruction is to invite guest speakers to talk to your class about careers in or related to electricity and electronics.

Unit: Exploring Electricity/Electronics

Lesson 1: Introduction to Electricity

Objectives

A. Following a discussion, students will be able to:
  - -identify a definition for electricity.
  - -list the three basic parts of an atom and identify their electrical charge.
  - -identify the law of electrical charges.
  - -identify a definition for potential difference.
  - -identify the difference between conductors and insulators.
  - -list the four basic parts of an electrical circuit.

Lesson Content

A. Introduction to electricity
  1. Electricity is the flow of electrons through a conductor.
  2. Parts of an atom.
     a. electrons (-)
     b. protons (+)
     c. neutrons
  3. The first law of electrostatics
     a. unlike charges attract
     b. like charges repel
  4. Free electrons
     a. electrons that move from one atom to another
     b. conductors contain many free electrons
     c. insulators contain very few
  5. Potential difference is an excess of electrons at one terminal and a deficiency at another terminal
  6. Current
     a. is a flow of electrons in one direction.

Learning Activities

A. Teacher Guided Discussion
  1. Ask students if they have ever seen electricity. Discuss how important electricity is to the way we live.
  2. Using OT #1-1, discuss a definition for electricity.
  3. Using OT #1-2, discuss the basic parts of an atom and their electrical charge.
  4. Using OT #1-3, discuss the first law of electrostatics and how it applies to atoms.
  5. Using OT #1-4, discuss the role of free electrons in conductors and insulators.
  6. Using OT #1-5, explain the concept of potential difference.
  7. Using OT #1-6, explain the concept of current.
  8. Using OT #1-7, discuss the four basic elements in an electrical circuit.

Ref.

  b. requires a continuous conductor path from positive to negative.

7. Basic circuit elements
   a. energy transducer
   b. conductor path
   c. output transducer
   d. control device

B. Following a demonstration in a lab activity, students will be able to:
- build a simple working continuity tester.
- use their continuity tester to identify conductors and insulators.
- use their continuity tester to identify defective electronic components

B. Making and using a continuity tester.
1. Making a continuity tester
   a. reading a schematic
   b. making the circuit
   c. testing the device
2. Using a continuity tester
   a. identifying conductors
   b. identifying insulators
   c. identifying defective components

B. Learning Activity
1. Explain the concept of continuity and discuss how continuity testers are used to locate defects in conductors.
2. Introduce students to the four basic parts of a continuity tester.
3. Demonstrate how to build a continuity tester. Emphasize how to handle electronic components and make good connections.
4. Provide students with HO #1-1 and the tools and materials needed to make a continuity tester.
5. Have students make their continuity testers.
6. Circulate around the room and provide individual instruction as needed.

7. When students have finished their continuity testers, demonstrate how to identify conductors, insulators, and defective components.
8. Divide the class into groups of about three to four students. Provide each group a variety of conductors, insulators and electrical components.
9. Have students complete the lab activity.
10. Collect and evaluate your students' continuity testers and lab sheets.

INTRODUCTION TO ELECTRICITY

Preparation Hints:

1. Review the materials provided, duplicate HO #1-1, and prepare the transparencies needed to present this lesson.

2. During this lesson, your students will be making simple continuity testers. Prior to implementing this lesson, you will need to collect and organize electrical components into simple kits. Each kit will need to include a nine volt battery, 450 ohm resister, LED, 9 volt battery snap connector with leads, four 1/2" long No. 8 pan head screws, two 12" long pieces of 18 gauge wire, and one piece of wood (5" long, 3" wide, and 3/4" thick). In addition, your students will need access to white glue, silicone glue, wire strippers, needle nose pliers, screw drivers and a drill equipped with an 1/8" drill bit. To save time, you may want students to use a drill press. To keep from losing the small electrical components, you may want to put each kit in a plastic bag.

3. During the lab activity, your students will be using their continuity testers to identify conductors and insulators. Prior to implementing this lesson, you will need to collect a variety of materials for your students to test. You will want to include things like wood, plastic, aluminum, steel, copper, rubber, water, glass, and ceramics. They can be in the form of things like aluminum foil, rubber erasers, steel paper clips, etc.

4. During the lab activity, your students will be using their continuity testers to test a variety of electrical components. Prior to implementing this lesson, you will need to collect things like light bulbs, speakers, fuses, and sections of wire. It is important that some of the components that you collect are defective. You may want to ask a local service technician to help you collect the defective components.

Content Presentation Hints:

1. Electricity is often thought to be magic. Unlike a small gasoline engine, opening the back of an electronic device does not reveal how it works. A basic introduction to the atom, the law of electrostatics, and the concept of potential difference is essential to take the mystery out of electricity.

2. When discussing the four basic parts of an electrical circuit, draw several diagrams on the chalk board representing a common electrical circuit. Your diagrams could feature things like a flashlight, a starting system for an automobile, and an electrical light in a home. Ask students to identify the energy transducer, conductor path, output transducer, and control device in each diagram (see Figure 1-1).

Learning Activity Hints:

1. When showing students how to build their continuity tester, demonstrate how to bend the leads on resisters and LED's so they will loop around the screws. Make sure students understand they need to wrap the leads around the screws in a clockwise direction so they tighten when the screws are tightened. In addition, show students how to identify the positive and negative leads on an LED. Stress the importance of observing polarity when installing an LED into a circuit.

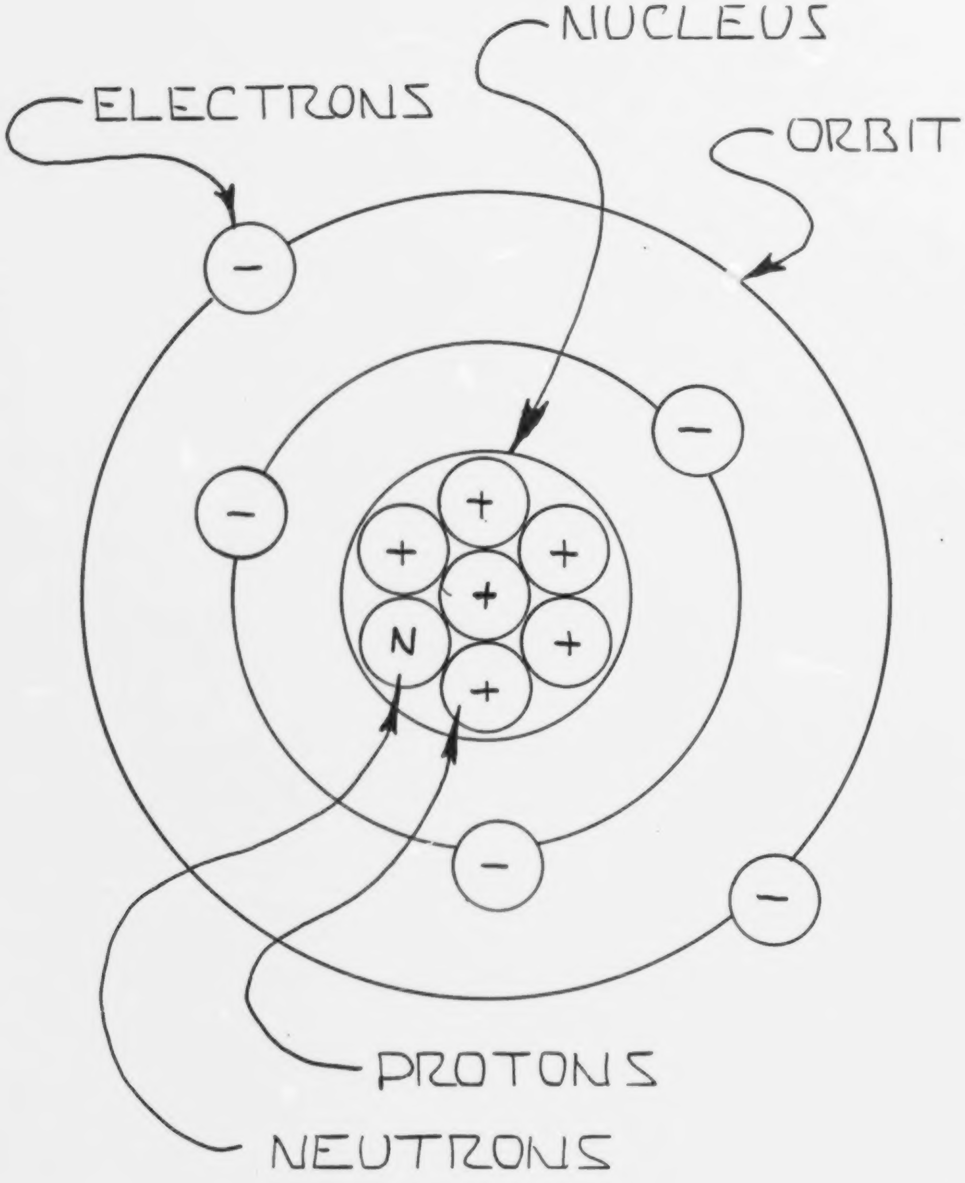
2. Demonstrate how to use a continuity tester to identify conductors and insulators. During the demonstration, draw a heavy black pencil line on a piece of paper. The line should be about 3 inches long and at least 1/8 inch wide. Test the line with the continuity tester. It should prove to be a conductor.

3. When preparing materials for students to test, obtain several 6 inch lengths of four - conductor telephone cable (see Figure 1-2). Expose and strip the wires at both ends of each cable. At one end of each cable, short two of the four wires together. Insulate the remaining wires and hide the short with electrical tape. During the lab activity, ask students to use their continuity tester to identify which of the four wires are shorted together in each sample.

4. Consider making several quiz boards for your students to use with their continuity testers. To make the board, write a multiple choice question on an 8 1/2" by 11" piece of hardboard (see Figure 1-3). Drill a hole after the question and before each possible answer. Install a nut and bolt in each hole. On the back side,

connect the bolt after the question to the bolt before the correct answer with a piece of 24 gauge wire. Fasten a second piece of hardboard to the back of the quiz board to hide the connection. During the lab activity, ask students to answer the question by touching one lead of their continuity tester to the bolt after the question, and the second test lead to a bolt near a possible answer. If their LED lights, they have answered the question correctly. If the LED does not light, they need to try again.

Electricity is the flow of electrons through a conductor.


NUCLEUS
ELECTRONS
ORBIT
−
−
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N
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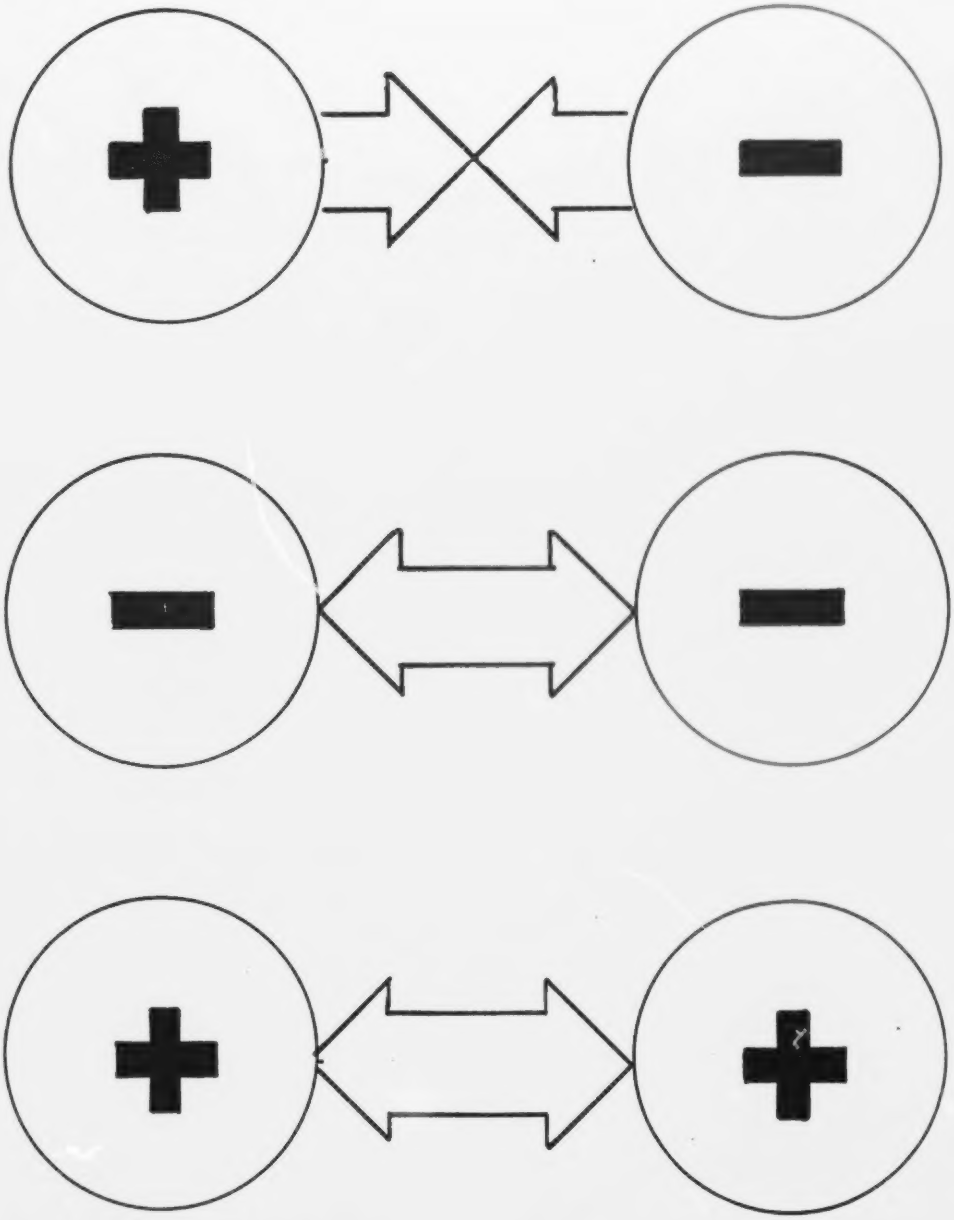
−
PROTONS
NEUTRONS

OT #1-3

The first law of electrostatics:

* unlike charges attract
* like charges repel



OT #1-4

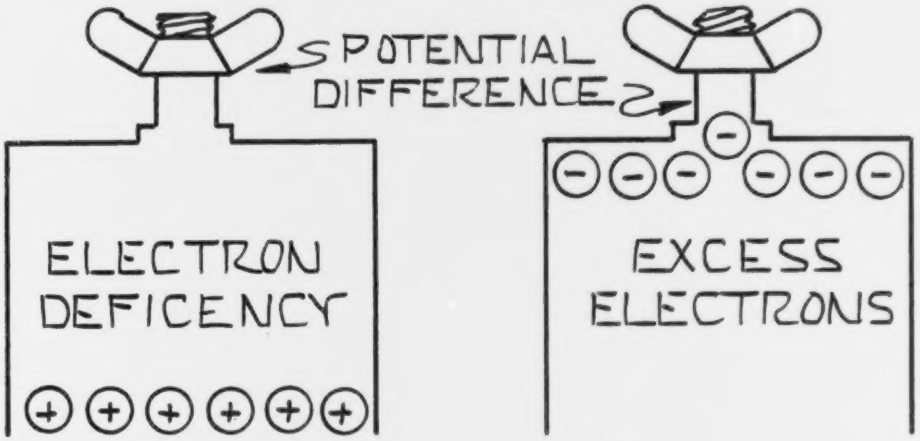
Free electrons:

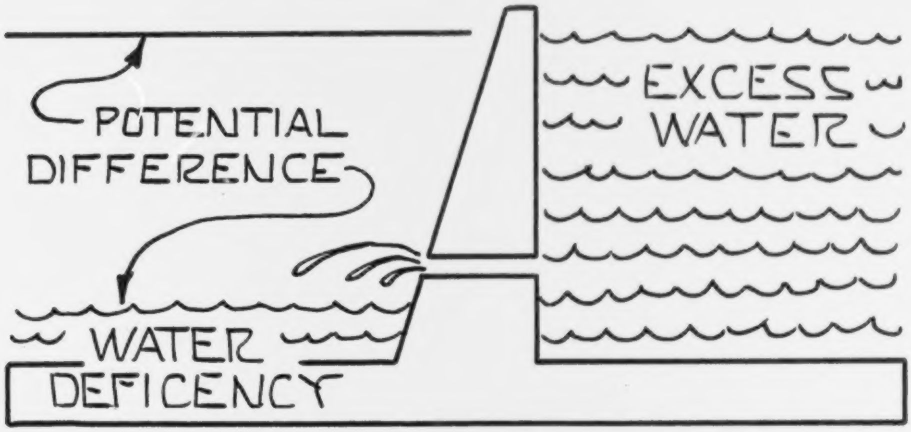
* electrons that move from one atom to another
* conductors contain many free electrons
* insulators contain very few

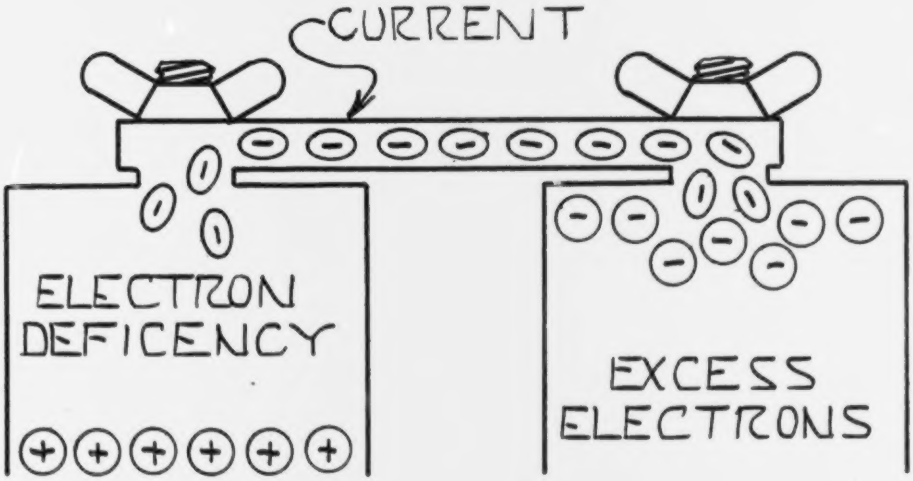
OT #1-6

Current:

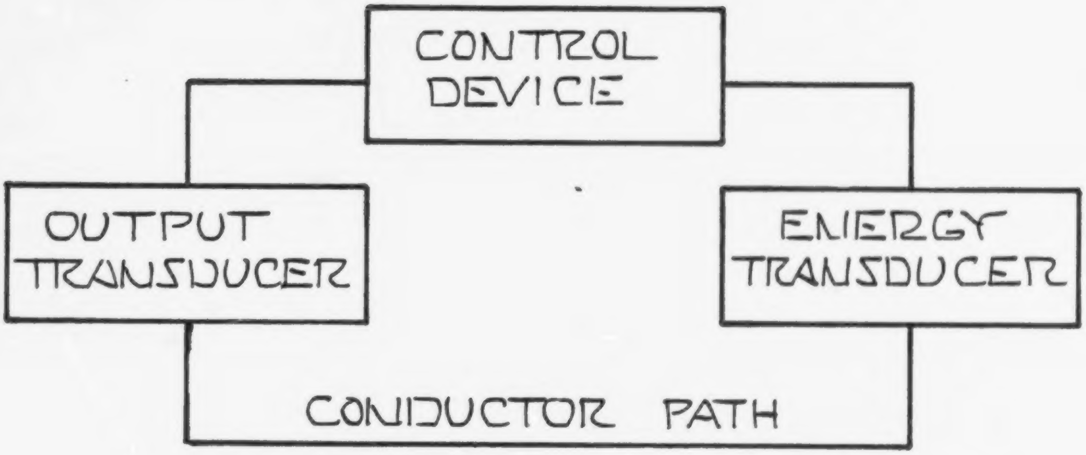
* is a flow of electrons in one direction.
* requires a continuous conductor path from positive to negative.

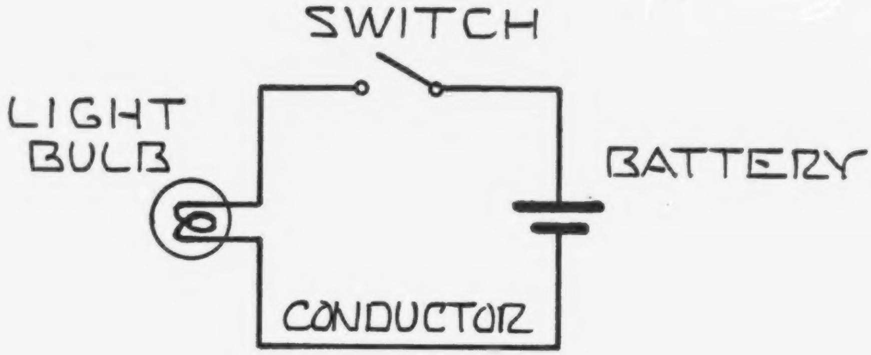

POTENTIAL
DIFFERENCE
ELECTRON
DEFICENCY
EXCESS
ELECTRONS


POTENTIAL
DIFFERENCE
EXCESS
WATER
WATER
DEFICENCY


CURRENT
ELECTRON
DEFICENCY
EXCESS
ELECTRONS

OT #1-7


CONTROL DEVICE
OUTPUT TRANSDUCER
ENERGY TRANSDUCER
CONDUCTOR PATH


SWITCH
LIGHT BULB
BATTERY
CONDUCTOR

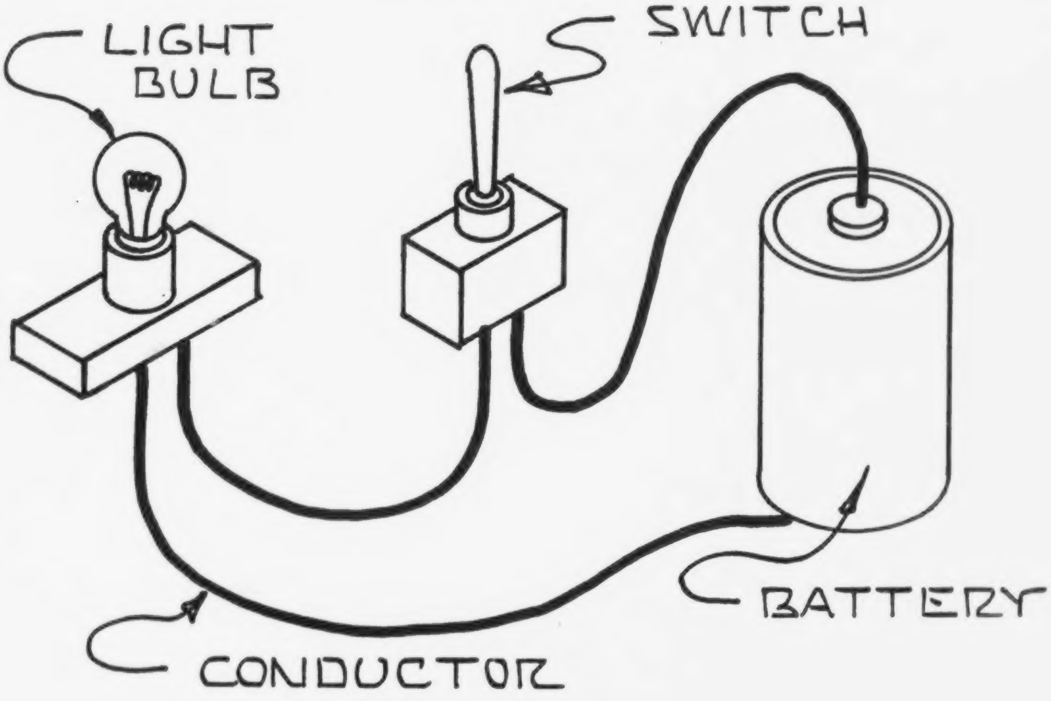

LIGHT BULB
SWITCH
BATTERY
CONDUCTOR

Figure 1-1, Example Electrical Systems

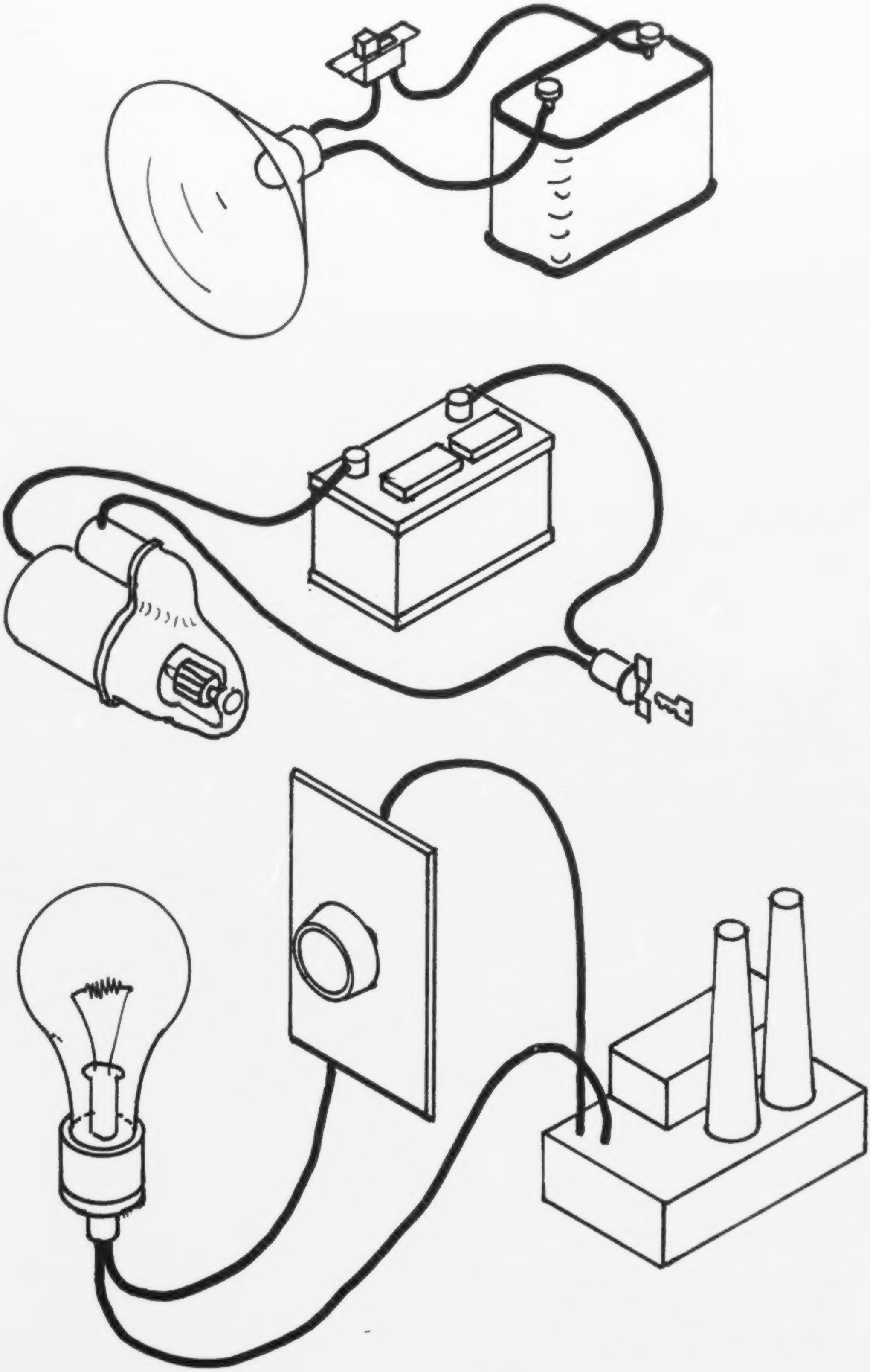


Figure 1-2
Telephone Cable
Trouble Shooting

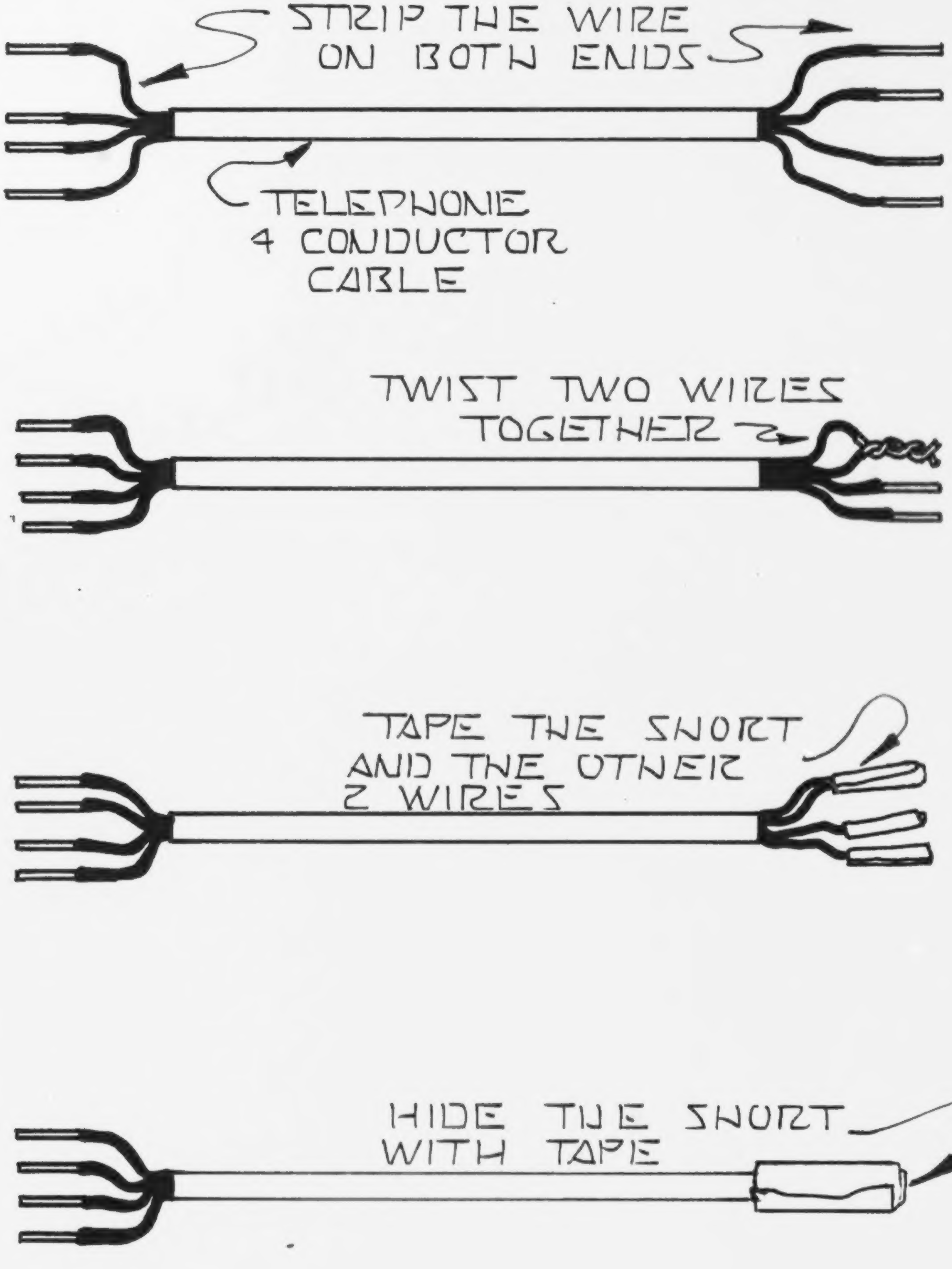
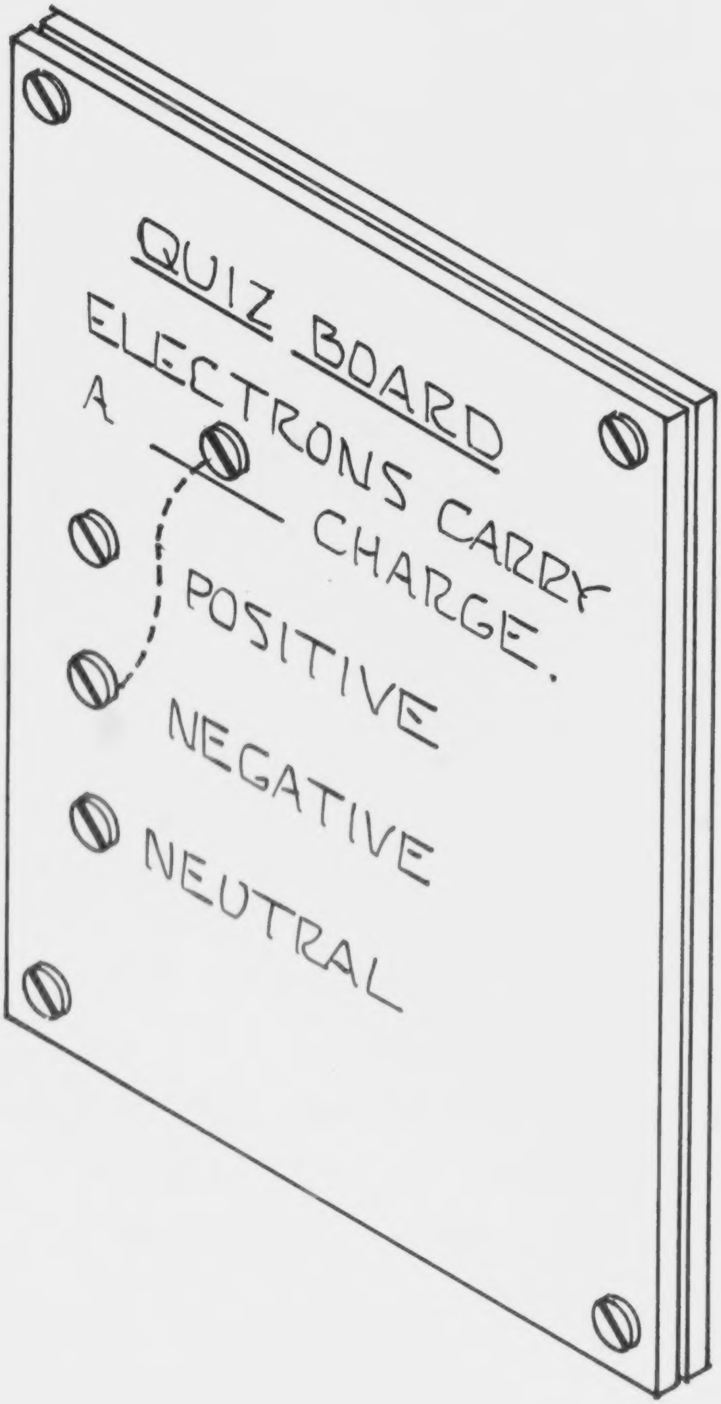


Figure 1-3
Quiz Board



INTRODUCTION TO ELECTRICITY

Discussion:

Electricity is used every day to power electronic devices like stereos, televisions, video recorders, computers, and electronic games. We often take electricity for granted, until we try to live without it. Electricity is visible during an electrical storm in the form of lightning. When lightning damages power lines, we experience what it is like to live without electricity. The clocks stop, the refrigerator does not stay cold, and we must light our room with candles.

Electricity is not magic. Instead, it is the flow of electrons through a conductor. To understand this definition, you need to learn about electrons, current, and conductors.

All materials are made of a collection of atoms. Atoms have three basic parts: neutrons, protons, and electrons. The neutrons and protons form a nucleus at the center of the atom. Electrons are the smallest part of an atom. They rotate around the nucleus the same way the planets in our solar system rotate around the sun (see Figure 1-4).

No one is really sure what holds an atom together. Scientists use what they do know to form theories. They believe an electrostatic force holds electrons in their orbit around the nucleus. They also believe electrons have a negative electrical charge and protons have a positive electrical charge. The neutrons are neutral. They do not have a positive or a negative charge. According to the first law of electrostatics, unlike charges attract each other and like charges repel each other. Since the electrons have a negative charge and the protons have a positive charge, they attract each other. This attraction is thought to hold atoms together.

Different materials have different atoms. Some materials have atoms with only a few electrons while others have a lot of electrons. The atoms in some materials do not have enough electrostatic force to hold the electrons in the outer most orbits. These electrons can break free and move from one atom to another. The electrons that bounce from one atom to the next are called free electrons.

When the number of electrons and protons in an atom are equal, the atom is thought to be balanced. However, if an atom has more protons than electrons, it is thought to have a positive charge and it is called a positive ion. If an atom has more electrons than protons, it is thought to have a negative charge and it is called a negative ion. Positive ions attract free electrons until they become negative ions. Negative ions give up electrons until they become positive ions. This random exchange of electrons goes on inside many materials.

The random drift of electrons from one atom to another can not be used to perform work. To perform work, the free electrons need to flow in one direction. The force that attracts electrons to flow through a material in a purposeful way is called electromotive force. We can create the electromotive force by creating an excess of electrons at one end of a material. We will call this end the negative terminal. At the other end of the material, we will need to create a deficiency of electrons. Let's call this end the positive terminal (see Figure 1-5).

The excess of electrons at one terminal and the deficiency at the other terminal is called a potential difference. Potential difference in an electrical system is a lot like a lake with a dam. On one side of the dam there is a lot of stored water. On the other side of the dam, we have very little water. If we put a hole in the dam, the water will begin to flow from one side to the other. The water flows because there is a difference in water levels on each side of the dam. When the water levels become equal, the water will stop flowing because the potential difference is gone (see Figure 1-6).

In an electrical system, the electrons at the negative terminal are repelling each other and are attracted to the protons at the positive terminal. When a material with a lot of free electrons is placed across the two terminals, the electrons will push and shove their way from negative to positive. This flow of electrons in one direction is called current.

Materials that have a lot of free electrons are called conductors. Gold, copper, and aluminum are good conductors because they can carry electrical current. Materials like plastic, rubber, and porcelain have very few free electrons. They are called non-conductors or insulators.

To carry electrical current, you need a continuous conductor path from the positive terminal to the negative terminal. This continuous conductor path is called a circuit. A circuit that can perform work has four basic parts. They are as follows:

- energy transducer
- conductor path
- output transducer
- control device

The energy transducer provides the potential difference needed to produce an electrical current. A battery is an example of an energy transducer. The conductor path carries electrical current from the negative terminal to the positive terminal. Copper wire is often used for a conductor path. The output transducer uses the current to perform work. A light bulb is an example of an output transducer. The control device provides a way to control the current. A switch is a common control device. Together, they make a basic electrical system (see Figure 1-7).

Electricity is the flow of electrons through a conductor. Electrons are the smallest part of an atom and they carry a negative charge. The force that causes the electron to flow is called electromotive force. It is based on the fact that unlike charges attract and like charges repel. It is caused by an excess of electrons at the negative terminal and a deficiency at the postitive terminal. If a conductor is placed across the two terminals, their potential differences cause electrons to flow from the negative terminal to the positive terminal. This flow of electrons in one direction is called current. A basic circuit that can perform work includes an energy transducer, a conductor path, an output transducer, and a control device.

Learning Activities:

Electricians, electronic technicians, and electrical engineers use a variety of instruments to build, test, and service electrical systems. One of the most commonly used instruments is called a continuity tester. Continuity comes from the word continuous (without gaps or breaks). During this lab activity, you will build a simple continuity tester. When your tester is complete, you will use it to identify conductors and insulators. Later in this unit, you will use your continuity tester to troubleshoot circuits.

An electrical circuit must have a continuous conductor path to work. Continuity testers are used to locate defects in a conductor path. A simple continuity tester has four basic parts. A battery (energy transducer) an LED (output transducer), a resistor (control device), and two test leads (parts of the conductor path) (see Figure 1-8).

When a continuity tester is not being used, it is an open circuit. The conductor path between the negative and positive terminal on the battery is incomplete. Current will not flow and the LED will not light. When the test leads touch a good conductor, the circuit becomes complete and the LED lights. If the test leads touch a defective conductor, the circuit remains incomplete and the LED will not light.

Making a Continuity Tester

1. Make sure you have the parts you need to build your continuity tester. You will need:

    * 1 - 9 volt battery
    * 1 - 450 ohm resistor
    * 1 LED (Light Emitting Diode)
    * 1 - 9 volt battery snap connector with leads
    * 4 - 1/2" long number 6 pan head screws
    * 2 pieces of wire 12" long
    * 1 piece of wood, 5" long, 3" wide, and 3/4" thick

2. Spread a thin film of glue on the top of your block of wood. Locate your schematic on the block of wood so the boarders of the drawing line up with the edges of the wood. Smooth the air bubbles out from underneath the schematic and allow it to dry for a few minutes. Cut off the excess paper around the edges of your wood block.

3. Using a 1/8" bit, drill holes about 1/2" deep at each of the locations shown on the schematic. Drive a pan head screw about half way into each hole.

4. Find the location for the 450 ohm resistor on the schematic. Place the resistor in its location and loop each lead clockwise around the screws.

5. Find the location for the LED on the schematic. Bend the leads VERY carefully so they will touch each screw. Place the LED in its location. Make sure the longer lead (+) is touching the screw connected to the resistor. Carefully loop each lead clockwise around their screws.

6. Find the location for the nine volt battery snap connector. Loop the red lead clockwise around the screw leading to the resistor. You may need to strip more insulation off the wire so it will wrap all the way around the screw. Loop the black lead on its screw.

7. Strip about 1/2" of insulation off each end of 12" long wires. Loop one end of one wire around the screw leading to the LED. Loop one of the other wires around the screw leading to the negative terminal on the battery.

8. Tighten each screw, being careful not to over tighten. You do not want to distort the leads or drive the connections into the wood.

9. Fasten the snap connector to the nine volt battery. Apply a 1" bead of silicone glue where the battery will be located. Push the battery into the glue and allow to dry.

10. Test your continuity tester by touching the ends of the test leads together; the LED should light. If it does not, check your battery, connections, and LED. If it still does not work, ask your teacher for assistance.

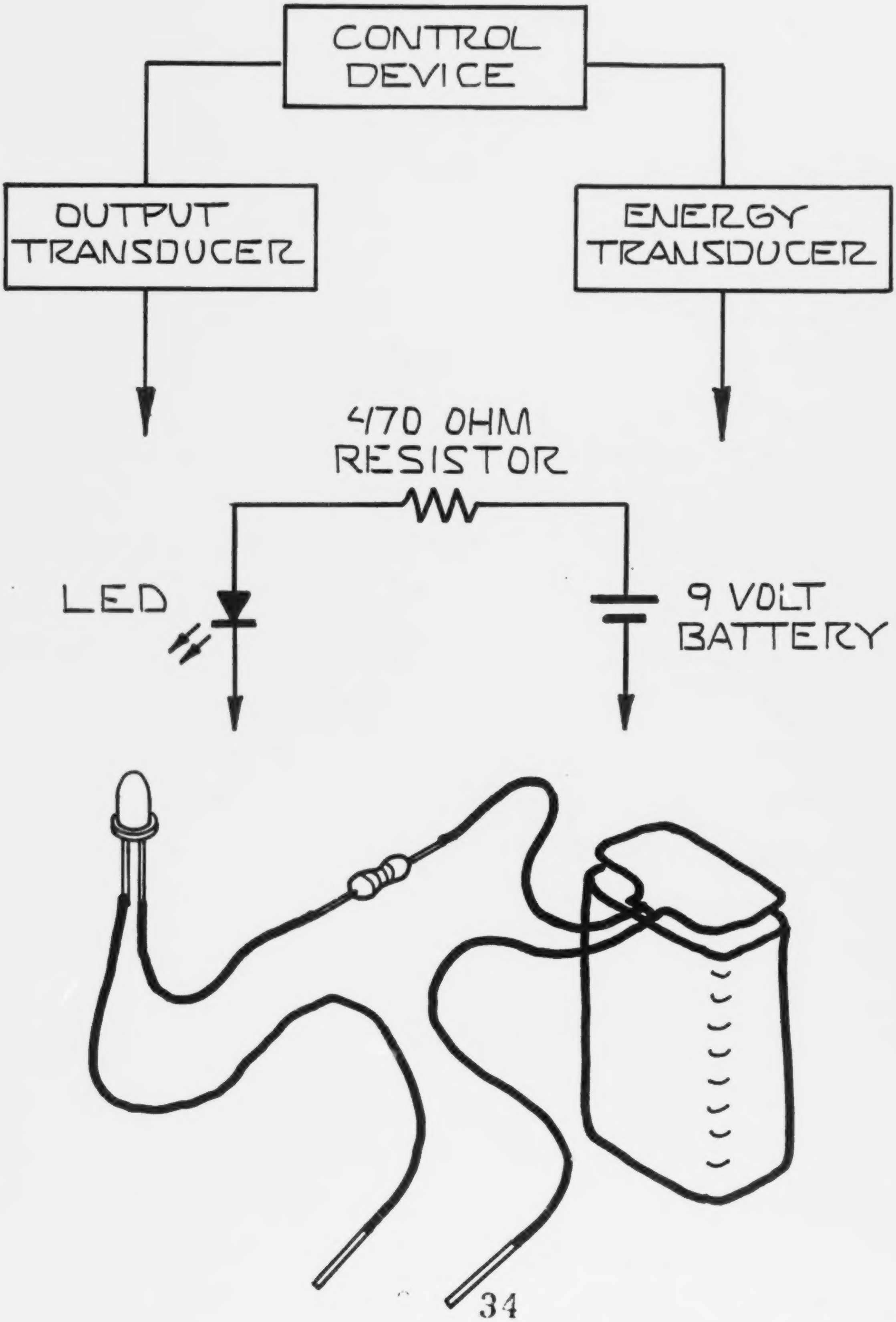
Using a Continuity Tester:

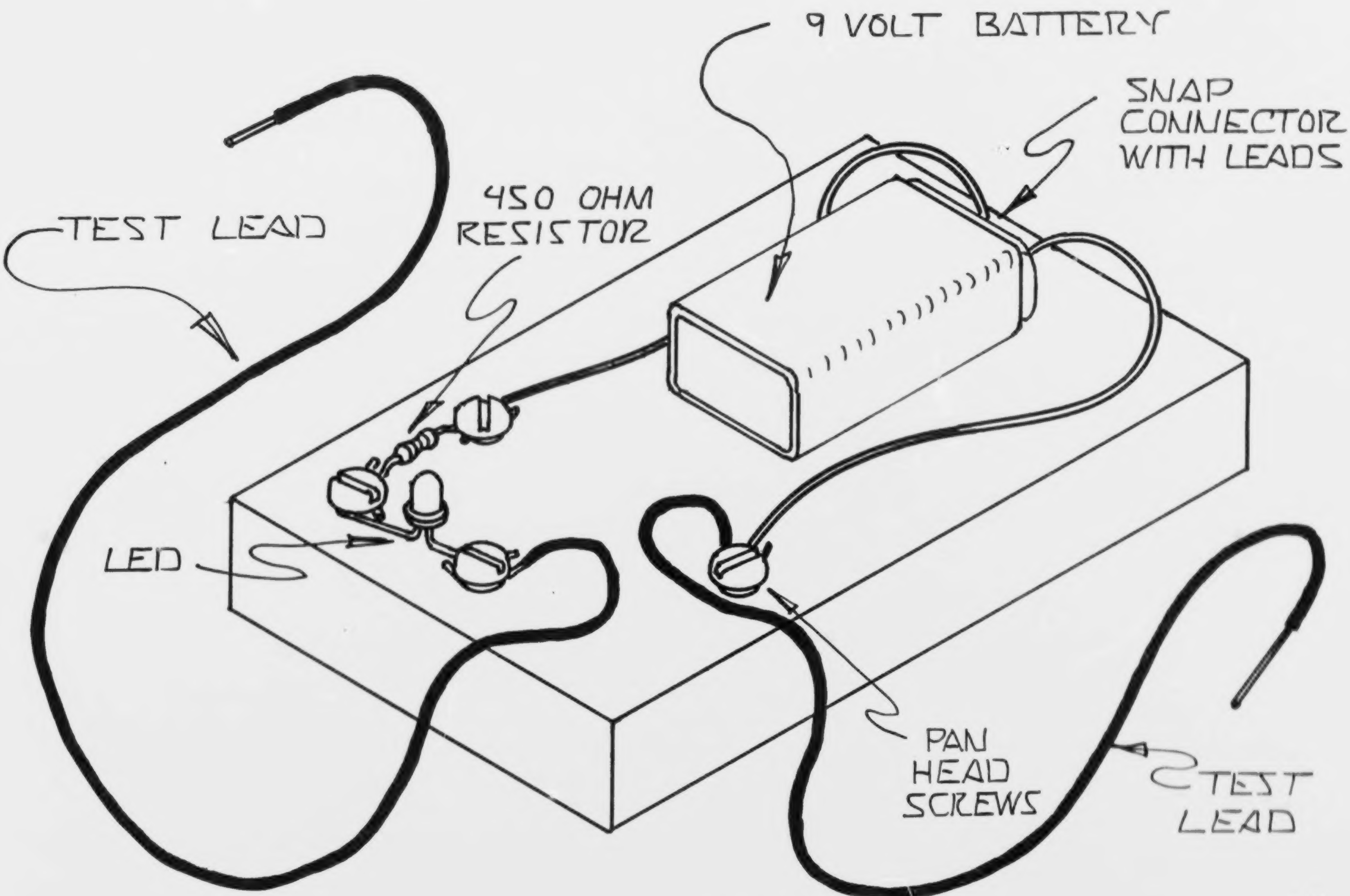
1. A continuity tester can be used to identify conductors and insulators. Your teacher will provide you with a variety of materials. Test each material by touching with the test leads on your continuity tester. Make sure your test leads do not touch each other during the test because you will get a false reading. If the LED lights up, current can pass through the material and it should be listed under CONDUCTORS. If the LED does not light up, current can not pass through the material and it should be listed under INSULATORS.

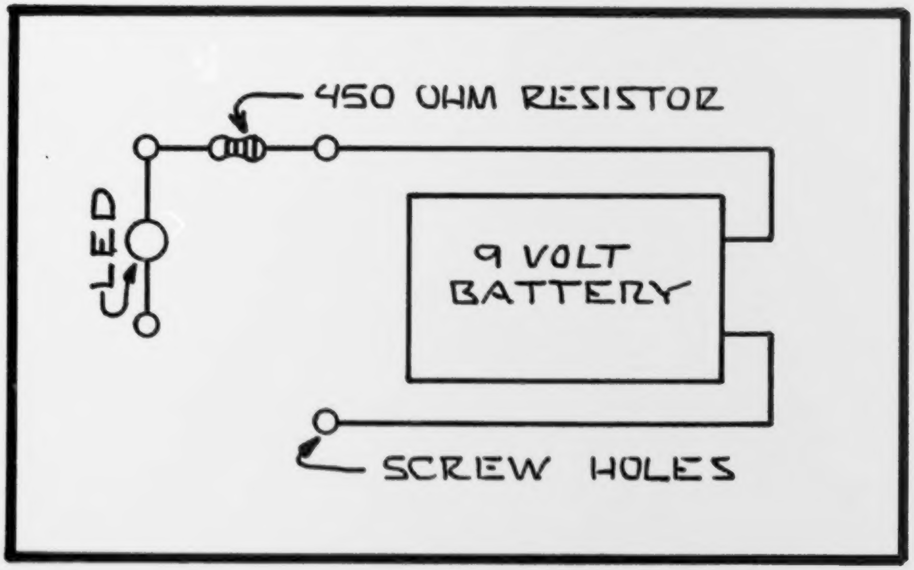
CONDUCTORS	INSULATORS

2. A continuity tester can also be used to test electrical components (parts). Your teacher will provide you with a variety of electrical components. Write the name of each component in the blanks provided. Test each part and identify whether they are good or defective.

COMPONENTS	TEST RESULTS
	Good or Defective
	Good or Defective
	Good or Defective
	Good or Defective
	Good or Defective
	Good or Defective


CONTROL DEVICE
OUTPUT TRANSDUCER
ENERGY TRANSDUCER
470 OHM RESISTOR
LED
9 VOLT BATTERY


9 VOLT BATTERY
SNAP CONNECTOR WITH LEADS
450 OHM RESISTOR
TEST LEAD
LED
PAN HEAD SCREWS
TEST LEAD



CONTINUITY TESTER SCHEMATIC

Unit: Exploring Electricity/Electronics

Lesson 2: Energy Transducers

Objectives

A. Following a discussion, students will be able to:
- identify a definition for energy transducer
- explain why electricity is referred to as a second generation source.
- identify the four basic types of primary energy sources for electrical systems.
- identify four examples of energy transducers.
- complete flow charts illustrating the energy conversion process for batteries, thermocouples, photovoltaic devices, and electromagnetic generators.

Lesson Content

A. Energy transducers
1. electricity
   a. a second generation energy source
   b. requires a primary energy resource.
2. Energy transducers convert a primary energy resource into electrical energy.
3. Primary energy resources
   a. chemical
   b. thermal (heat)
   c. radiant (light)
   d. mechanical (motion)
4. Basic energy transducers
   a. batteries
   b. thermocouples
   c. photovoltaics
   d. electromagnetic generators
5. Batteries
   a. convert chemical energy to electrical energy
   b. require two dissimilar metals and electrolyte

Learning Activities

A. Teacher Guided Discussion
1. Ask students where electrical energy comes from. Explain how electrical energy is a second generation energy source.
2. Using OT #2-1, explain the definition for an energy transducer.
3. Using OT #2-2, discuss the four basic types of primary energy resources.
4. Using OT #2-3, introduce students to four examples of energy transducers.
5. Using OT #2-4 through OT#2-7, explain how each energy transducer converts a primary energy resource to electrical energy. Identify the basic elements used in each energy transducer.

Ref.

6. Thermocouples
    - a. convert thermal energy to electrical energy
    - b. require two dissimilar metals and heat
7. Photovoltaics
    - a. convert radiant energy to electrical energy
    - b. require a positive silicon layer, a negative silicon layer and sunlight.
8. Electromechanical generators
    - a. convert mechanical energy to electrical energy
    - b. require a magnetic field, coiled conductor, and motion

B. Following a demonstration in a lab activity, students will be able to:

- use common materials to make a simple working battery and electromagnetic generator.
- measure the output voltage and current from an energy transducer.
- connect photovoltaic and battery cells in series.

B. Making and testing energy transducers

1. Measuring voltage and current
   a. connecting meters
   b. reading meters
2. Batteries
   a. making a wet cell
   b. testing a wet cell
   c. connecting wet cells in series to make a battery
   d. testing a battery
3. Electromagnetic generators
   a. making a simple generator
   b. testing a simple generator
   c. testing a small generator
4. Photovoltaic cells
   a. testing a photovoltaic cell
   b. connecting photovoltaic cells in a series
   c. testing a photovoltaic ray
5. Thermocouples
   a. testing a thermocouple

B. Learning Activities

1. Demonstrate how to measure voltage and current using a meter(s)
2. Demonstrate how to construct a simple wet cell using common materials. Explain how to make a battery by connecting wet cells in series.
3. Demonstrate how to construct a simple electromagnetic generator. Explain how a hobby motor can serve as a generator.
4. Demonstrate how to orient a photovoltaic cell to a light source. Explain how to connect photovoltaic cells in series to form a photovoltaic ray.
5. Demonstrate how to test a thermocouple.
6. Provide students HO #2-1 through HO # 2-5. Divide the class into groups of three to four students.

7. Assign each group a work station and have them complete the lab activity. When students have finished the lab, rotate them to the next work station.
8. Circulate around the room providing individual instruction as needed.
9. When students have finished all four lab activities, ask students questions about the characteristics of each energy transducer.
10. Collect and evaluate the lab sheets for all four energy transducers.

Energy Transducers

Preparation Hints:

1. Review the materials provided, duplicate HO #2-1 through HO #2-5, and prepare the transparencies needed to present this lesson.

2. During the lab activity, your students will be making and testing a variety of energy transducers. Prior to implementing this lesson, you will need to collect and organize the materials listed in the handouts. If you do not have meters, check to see if they can be borrowed from the science department.

3. If you have to purchase new meters, consider purchasing digital multimeters. When compared to analog meters, digital meters are typically easier to use and read.

4. Photovoltaic cells, hobby motors, jumper leads, and LED's can be purchased from most electronic stores or vendors. Film containers are often thrown out when film is dropped off for processing. Ask your local camera or instant film processing store to help you collect the film containers you need to make batteries. Thermocouples can be purchased at a hardware store.

5. Prior to implementing this lesson, you will need to make the photovoltaic test apparatus illustrated in Figure 2-1. Photovoltaic cells are very expensive and delicate. Mounting them in a panel similar to the one illustrated will make them easier to handle and will extend their life considerably.

6. Prior to implementing this lesson, consider performing each of the lab activities. Performing the activities will help you test the materials, anticipate problems and develop strategies for assuring student success.

7. During a lab activity, your students will be working in teams of three to four. To determine how many lab stations you will need, divide the number of students in your class by three or four (whichever number works best for you). If you need more than four lab stations, consider setting up extra lab stations for making batteries since it is the most time consuming lab activity.

Content Presentation Hints:

1. Show students a variety of energy transducers. Your examples could include things like miniature batteries for watches and hearing aids, a battery for an automobile, a bicycle generator, a portable emergency generator, thermocouples for industrial applications, and electronic devices powered by photovoltaic cells.

2. Consider showing a film or videotape on batteries, electrical energy, or energy conversion devices.

Learning Activity Hints:

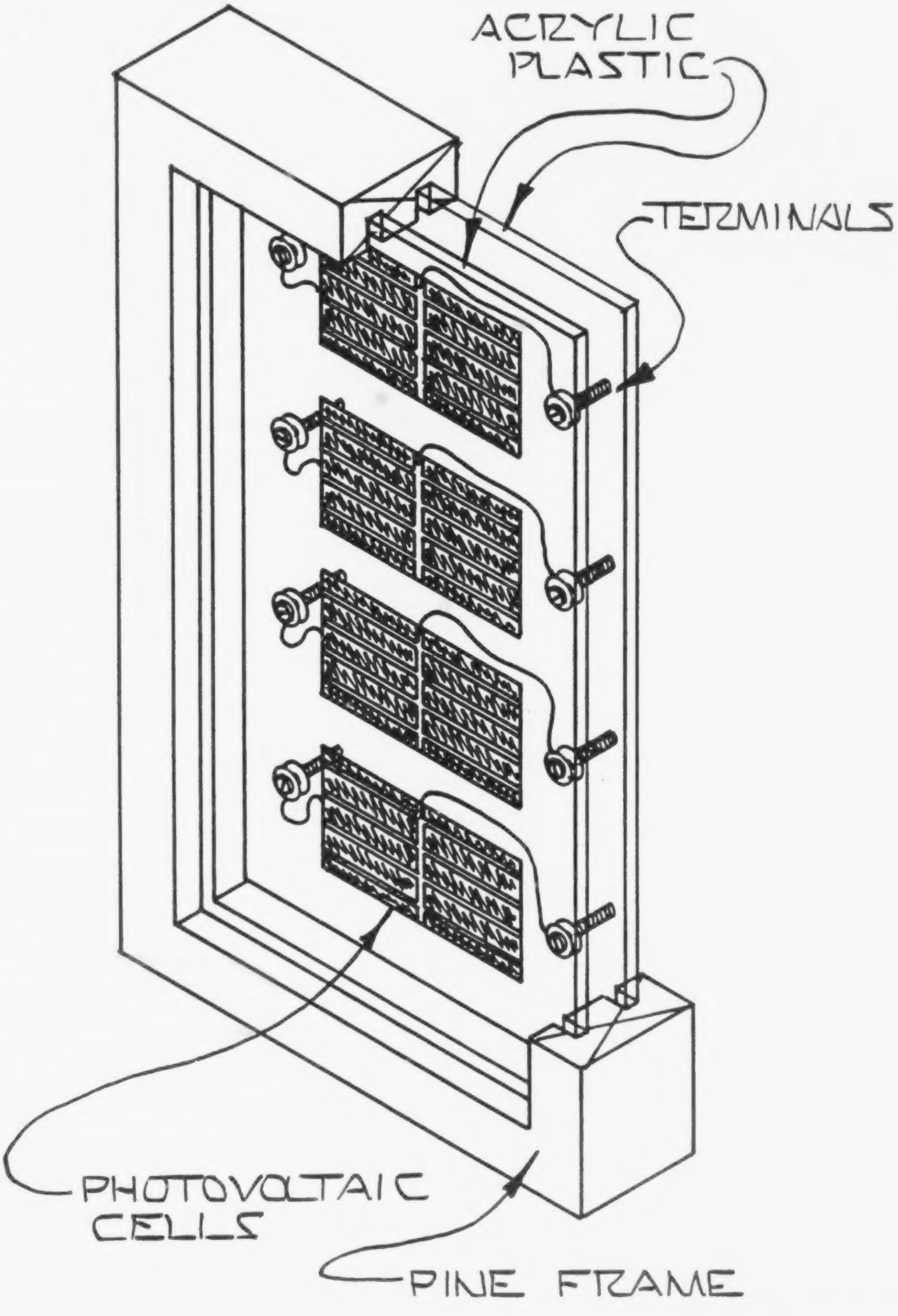
1. If time and/or materials are limited, instead of rotating groups of students through lab stations, conduct demonstrations on generators, photovoltaics, and thermocouples. During the lab activity, have each student make and test a wet cell. When the wet cells are finished, connect all the cells in series and measure the voltage and current produced by the class. In addition, you could ask the class to wire all the cells in parallel and measure the voltage and current produced. Lastly, you could compare the differences between connecting cells in a series or in parallel.

2. When students have finished making and testing their wet cells, you may want to have students repeat the lab activity using commercially made dry cell batteries. When students have finished both labs, they could compare the voltage and current produced by their homemade cells with that of the dry cells. In addition, students could experience using dry cell batteries to power larger and more energy consuming devices such as light bulbs and hobby motors.

3. During the electromagnetic generator lab, you could have students measure the voltage and current output from an old bicycle generator. The generator could be fastened in a vice, driven by a variable speed electric drill and connected to a light bulb. Students could compare the voltage and current produced at slow speeds with that produced at high speeds. Based on data collected, students could conclude energy output is directly proportionate with energy input.

4. During the thermocouple lab, your students can make their own thermocouple by twisting the end of an iron wire and a copper wire together. Current will be produced if the joint is held over a flame. However, you will need to use a galvanometer to measure the current. You may be able to borrow a galvanometer from the science department.

FIGURE 2-1,
PHOTOVOLTAIC PANEL



OT #2-1

Energy transducers convert primary energy resource into electrical energy.

OT #2-2

Primary energy resources:

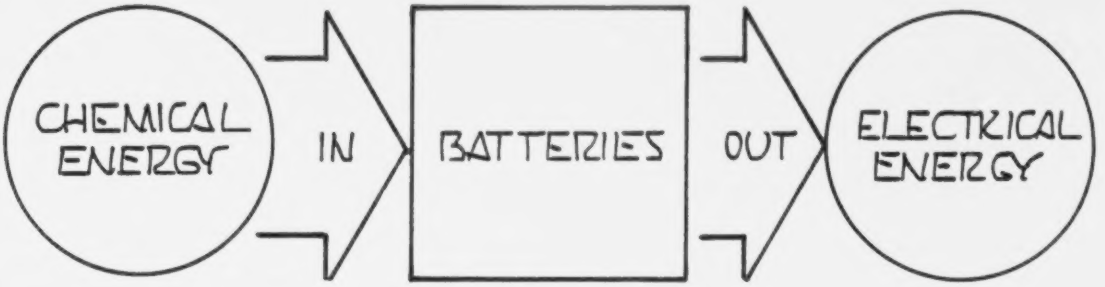
* chemical
* thermal (heat)
* radiant (light)
* mechanical (motion)

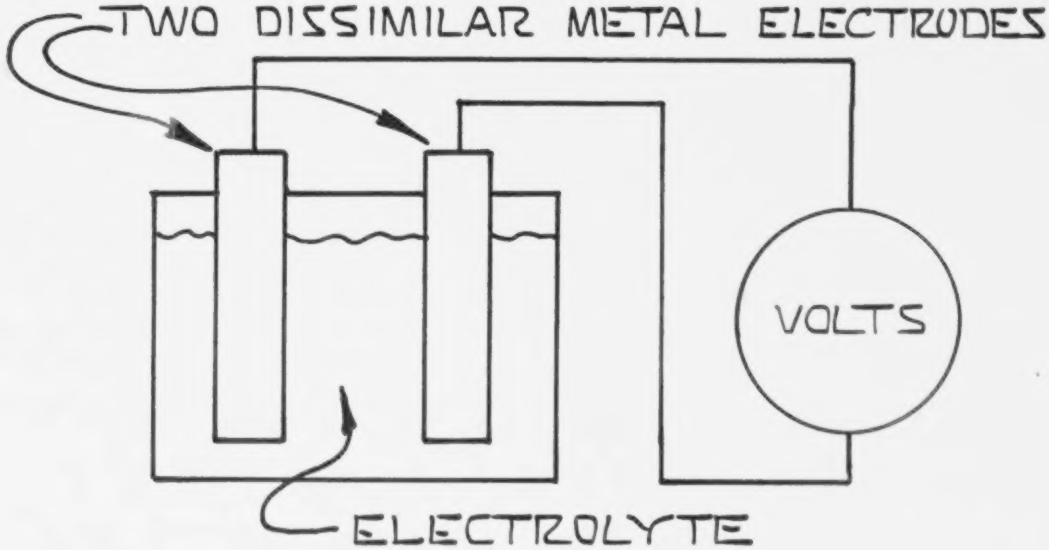
OT #2-3

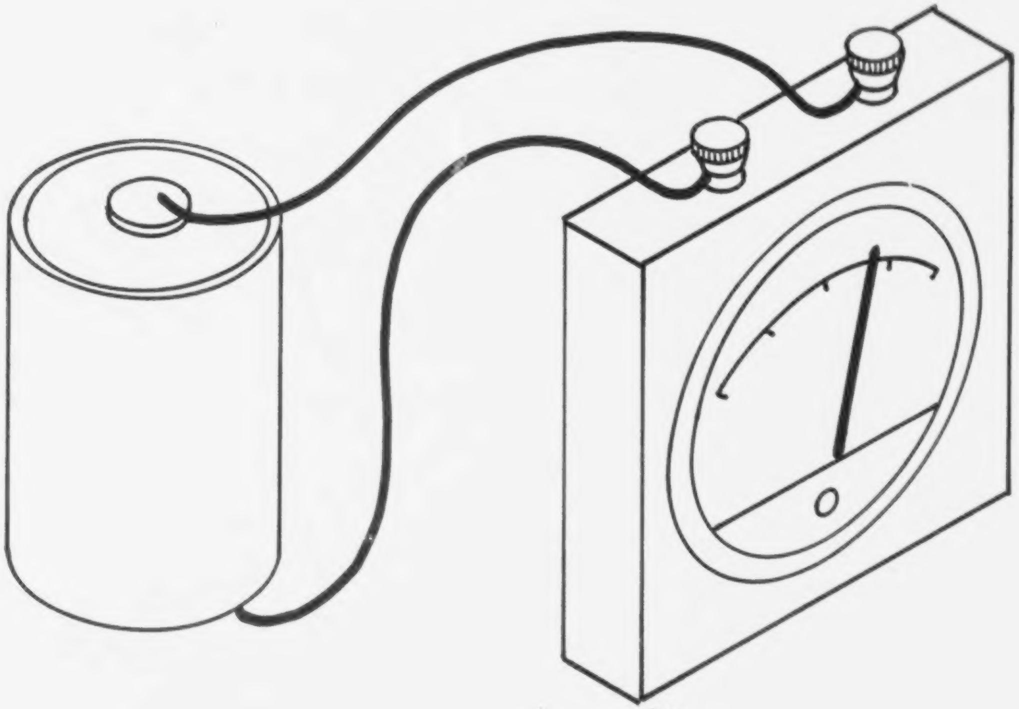
Basic energy transducers:

* batteries
* thermocouples
* photovoltaics
* electromagnetic generators

OT #2-4


CHEMICAL ENERGY
IN
BATTERIES
OUT
ELECTRICAL ENERGY


TWO DISSIMILAR METAL ELECTRODES
VOLTS
ELECTROLYTE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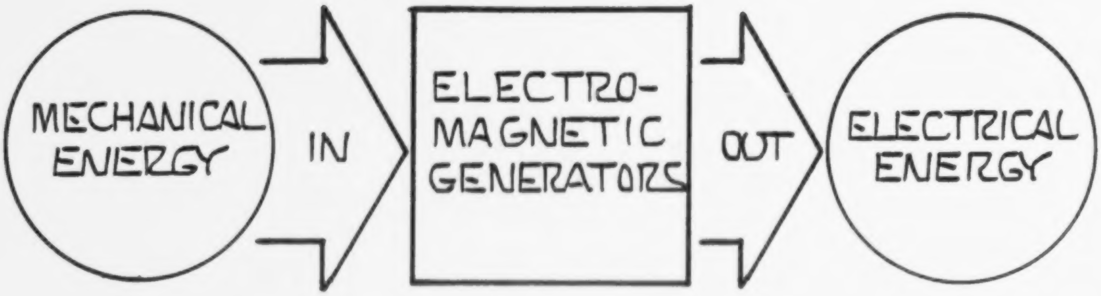
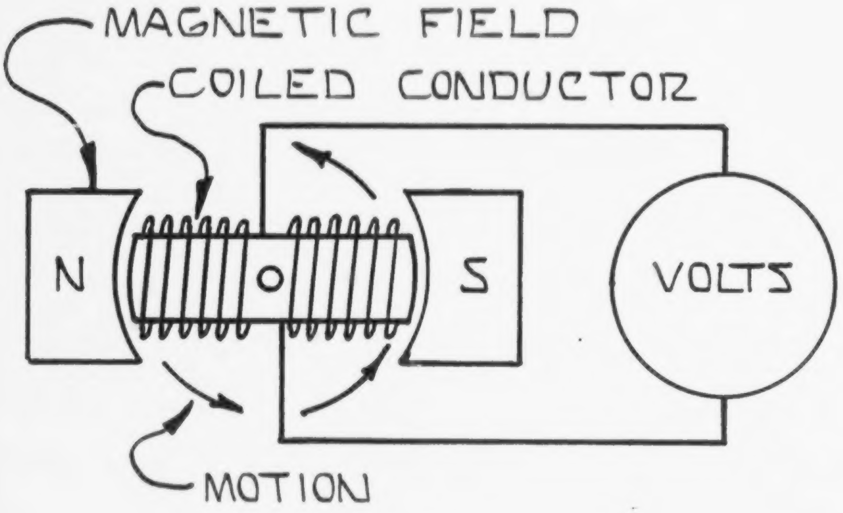
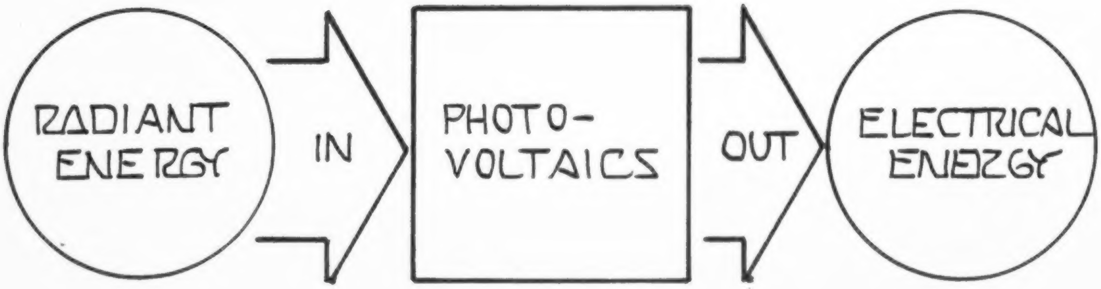
OT #2-5

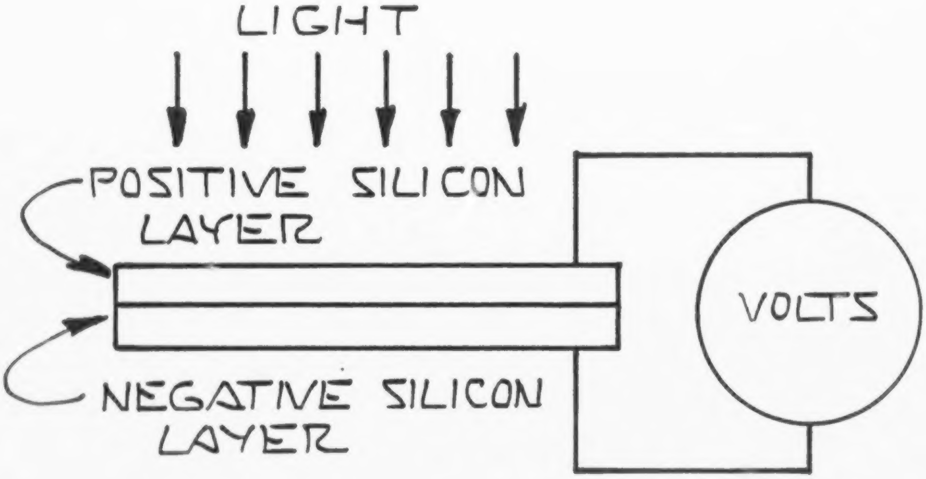

MECHANICAL ENERGY
IN
ELECTRO-MAGNETIC GENERATORS
OUT
ELECTRICAL ENERGY

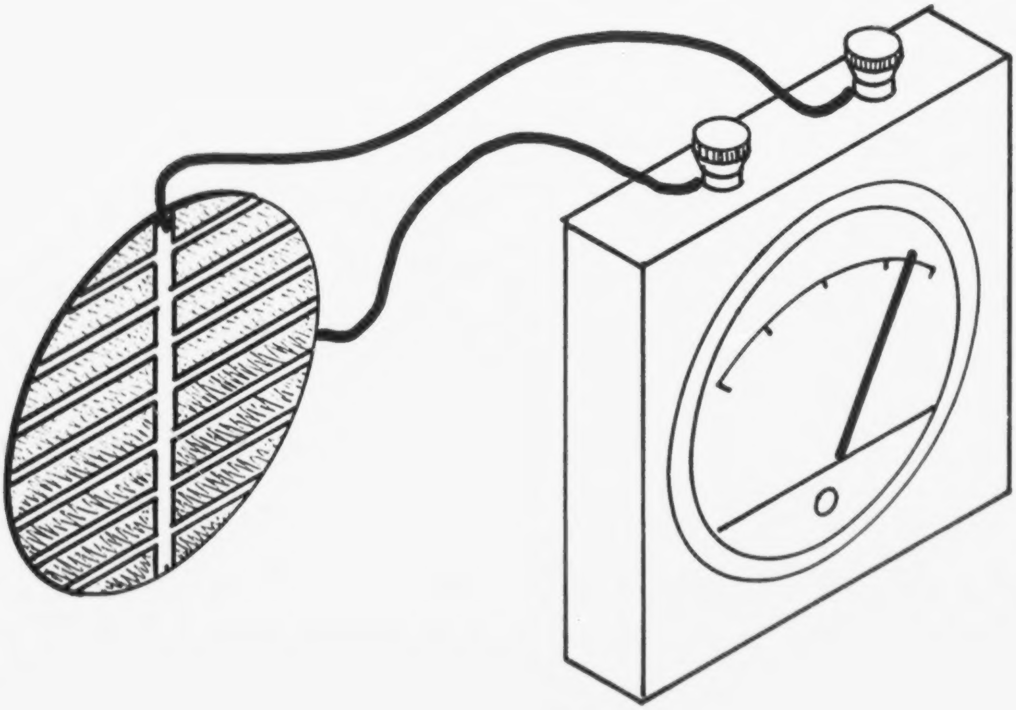

MAGNETIC FIELD
COILED CONDUCTOR
N
S
VOLTS
MOTION

0

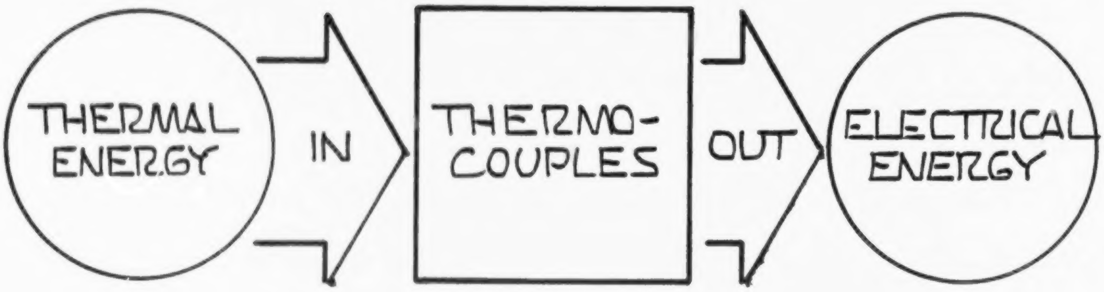
OT #2-6

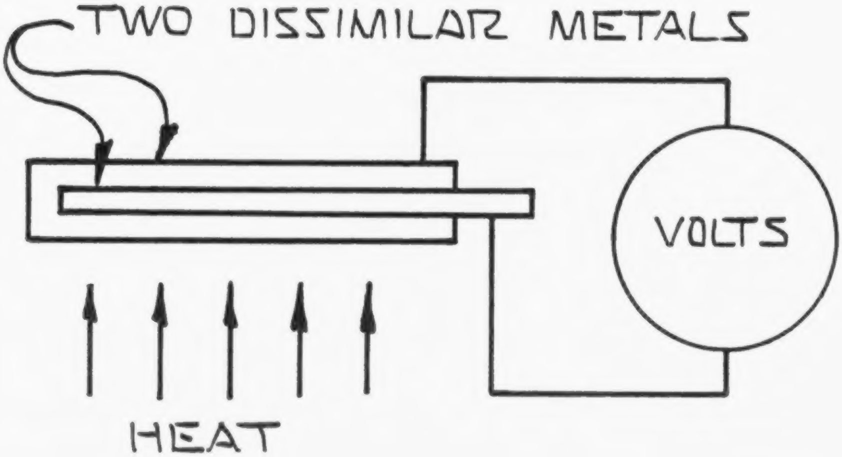

RADIANT ENERGY
IN
PHOTO-VOLTAICS
OUT
ELECTRICAL ENERGY

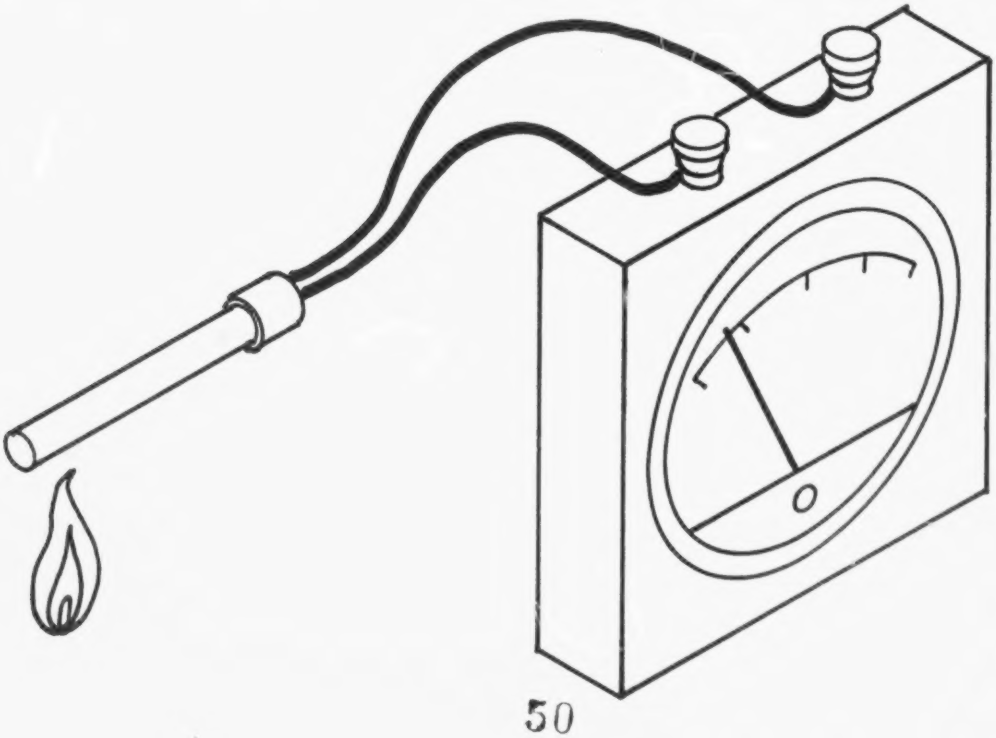

LIGHT
POSITIVE SILICON LAYER
NEGATIVE SILICON LAYER
VOLTS


0

OT #2-7


THERMAL ENERGY
IN
THERMO-COUPLES
OUT
ELECTRICAL ENERGY


TWO DISSIMILAR METALS
VOLTS
HEAT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Energy Transducers

Discussion:

Electricity is the flow of electrons through a conductor. To create electrical current, we need to apply a force that will knock electrons free of their atoms. This force is called electromotive force or emf. Electricity is called a second generation form of energy because we need to use another form of energy to produce emf. Emf can be produced with chemical, thermal (heat), radiant (light), or mechanical energy.

In an electrical circuit, emf is provided by an energy transducer. The energy transducers used in an electrical circuit convert either chemical, thermal, radiant, or mechanical energy into electrical energy. Examples of energy transducers include things like batteries, generators, photovoltaic cells, and thermocouples. All these devices use another form of energy to produce emf.

Batteries use a chemical solution called electrolyte and two electrodes made of different metals to convert chemical energy into electrical energy. When the electrodes are placed in the electrolyte, a chemical reaction occurs. The electrolyte causes one electrode to lose positive ions which gives it a negative charge. The positive ions in turn pull electrons from the other electrode giving it a positive charge. The chemical reaction creates a potential difference across the electrodes. If a conductor is connected across the electrodes, electrons will flow from the negative electrode to the positive electrode until the chemical energy inside the battery is depleted. Batteries are used to power portable devices like radios, flashlights, cameras, and toys.

Generators use magnetism to convert mechanical energy into electrical energy. Current flowing through a conductor will produce a magnetic field around the conductor. The opposite is also true. Passing a conductor through a magnetic field will produce current in the conductor. Generators use the relationship between magnetism and current to generate electricity. Three basic elements are needed to generate electricity, a coiled conductor, a magnetic field, and mechanical energy (motion). Mechanical energy is used to rotate coils of wire past magnets. The magnetic field produced by the magnets causes current to flow through the coils. The current flowing through the coils can be used to power electrical devices as long as there is mechanical energy to drive the generator. The electricity you use in your home comes from a generator.

Photovoltaic cells convert radiant (light) energy into electrical energy. The word photovoltaic comes from the word photo (light) and voltaic (generate electricity). Photovoltaic cells are made of two thin layers of silicon crystal. Each layer is specially treated to give them different electrical characteristics. When a photovoltaic cell is exposed to light, electrons flow from the negatively-charged silicon layer to the positively-charged layer. Photovoltaic cells are often used to power small calculators. In addition, photovoltaic cells are used to power the equipment aboard satellites.

Thermocouples convert thermal energy (heat) to electrical energy. When two different metals are put together and heated, a current can be produced. The metals heat at different rates. The difference in temperature between the two metals causes electrons to move. Thermocouples produce a very limited amount of current and can not be used to power devices. They are often used with other devices to measure and control thermal systems. For example, thermocouples are used to signal shut-off valves on gas furnaces and hot water heaters if the pilot light goes out.

Energy transducers produce the force needed to create current in a conductor. The force is measured in volts and current is measured in amperes or amps. Voltage can be measured by placing the test leads of a volt meter across the terminals of an energy transducer. Current is the quantity of electrons that pass a given point in the circuit during a given period of time. One ampere equals 6,250,000,000,000,000,000 electrons passing a point in the circuit in one second. To measure current, the meter needs to be installed in the circuit.

Electricity is called a second generation energy source because another form of energy is needed to create electromotive force. Devices that produce emf are called energy transducers. They convert either chemical, mechanical, radiant, or thermal energy into electrical energy. The emf produced by an energy transducer is measured in volts and current is measured in amperes.

Learning Activities:

You use a variety of energy transducers to power electrical devices. The energy needed to light the rooms of your house at night comes from a generator. Your portable stereo and/or tape player uses batteries for electrical energy. If you have a solar powered calculator, it relies on photovoltaic cells for electrical energy. All these energy transducers convert another form of energy into electrical energy. During the lab activities, you will be making and experimenting with a variety of energy transducers.

MAKING AND TESTING A BATTERY

To make a battery, you need two different metals and an electrolyte. Copper makes a good positive electrode and a galvanized (zinc coated) metal makes a good negative electrode. The electrolyte can be lemon juice, grapefruit juice, or table salt dissolved in water. With these materials you can make one of three batteries. Your teacher will tell you which battery to make.

Making a Citrus Cell

1. You can make a battery out of a piece of citrus fruit. Lemons and grapefruits work the best. They both contain the acid needed to produce the desired chemical reaction. To make a citrus cell, you will need:

    * 1 lemon or grapefruit
    * 1 small knife
    * 1 strip of galvanized metal 1/2" wide and 3" long
    * 1 strip of copper 1/2" wide and 3" long

2. Cut two slots into the top of the fruit with the knife. Make the slots at least 1" apart and 1 1/2" deep (see Figure 2-1).

3. Insert the copper strip into one slot and the galvanized strip into the other. Believe it or not, you have just made a battery.

Making a Simple Cell

1. To make a simple cell, you will need:

    * 1 35 mm plastic film container
    * 1 utility knife
    * 1 strip of galvanized metal 1/2" wide and 3" long
    * 1 strip of copper 1/2" wide and 3 " long
    * 1/4 cup of lemon juice, grapefruit juice, or salt water

2. Using the utility knife, cut two 1/2" long slots in the lid for the film container. The slots should be parallel and about 1/2" apart (see Figure 2-2).

3. Fill the film container about 2/3 full of electrolyte and snap the lid on the container.

4. Insert the galvanized strip of metal in one slot and the copper strip in the other. Make sure the strips are not touching each other inside the film container. You have just made a simple battery.

Making a Penny Cell

1. To make a coin battery, you will need:

   * 1 galvanized piece of metal about 1" wide and 1" long
   * 1 copper penny
   * 1 piece of paper towel about 3/4" wide and 3/4" long
   * 2 drops of lemon juice or vinegar
   * 1 eye dropper

2. Cut out a piece of paper towel about 3/4" wode and 3/4" long. Using the eye dropper, put one or two drops of lemon juice or vinegar on the paper towel until it is saturated.

3. Place the saturated paper towel in the center of the galvanized piece of metal. (See Figure 2-4.)

4. Put a penny on top of the saturated paper towel. You have just made a battery sandwich.

Testing your Cell

1. For this part of the lab activity, you will need:

   * 1 homemade cell
   * 1 milliamp meter
   * 1 volt meter

2. Now that you have made a cell, lets see if it works. Batteries use chemical energy to produce electromotive force. Electromotive force is measured in volts. Determine how many volts your battery can produce with a volt meter. Touch the positive lead from the meter to the copper electrode and touch the negative lead to the galvanized electrode (see Figure 2-_). Make sure you have a good connection. Read the meter and record the voltage in the space provided.

   __________ volts

3. Measure the current your battery can deliver using a milliamp meter. Current is measured in amperes. One milliamp is one thousandths of an ampere. Touch the positive lead from the meter to the copper electrode

and touch the negative lead to the galvanized electrode (see Figure 2-5). Make sure you have a good connection. Read the meter and record the current in the space provided.

__________ milliamps

Making and Testing a Battery

You probably noticed your cell does not produce a lot of volts or deliver a lot of current. Technically speaking, your cell is not really a battery yet. A battery is a collection of cells connected in series. When cells are connected in series, the total voltage will equal the sum of cell voltages. To make a battery that can perform work will require more cells. Use the material provided to make three more cells.

1. For the next part of the lab activity, you will need:

    - 4 homemade cells
    - 1 milliamp meter
    - 1 volt meter
    - 6 jumper leads
    - 1 LED

2. The next step is to connect your cells in series. To connect cells in series, the positive electrode from the first cell needs to be connected to the negative electrode of the second cell. The positive electrode from the second cell needs to be connected to the negative electrode of the third cell. This process is continued until all the cells are connectred together. Using jumper leads, connect your cells in series (see Figure 2-6). If you are making a battery with penny cells, simply stack the cells one on top of the other.

3. Measure the voltage produced by your battery with a volt meter. Touch the positive lead from the meter to the copper electrode on the fourth cell. Touch the negative lead from the meter to the galvanized electrode on the first cell. Read the meter and record the voltage in the space provided.

    __________ volts

4. Connect an LED to your battery (see Figure 2-7). Make sure the long lead on the LED is connected to the copper electrode. The LED should light. If it does not light, check all your connections.

5. Measure the current in the circuit with a milliamp meter. Connect the positive lead to the negative lead of the LED. Connect the negative lead to the galvanized electrode. Read the meter and record the current in the space provided.

__________ milliamps

6. When cells are connected in series, the total voltage is equal to the sum of the _____ voltages.

7. When cells are connected in series, the voltage in the circuit __. Circle the correct answer.

   A. increases
   B. decreases
   C. stays the same

8. When cells are connected in series, the current in the circuit _____. Circle the correct answer.

   A. increases
   B. decreases
   C. stays the same

9. Batteries convert _____ energy into electrical energy. Circle the correct answer.

   A. mechanical
   B. radiant
   C. chemical
   D. thermal

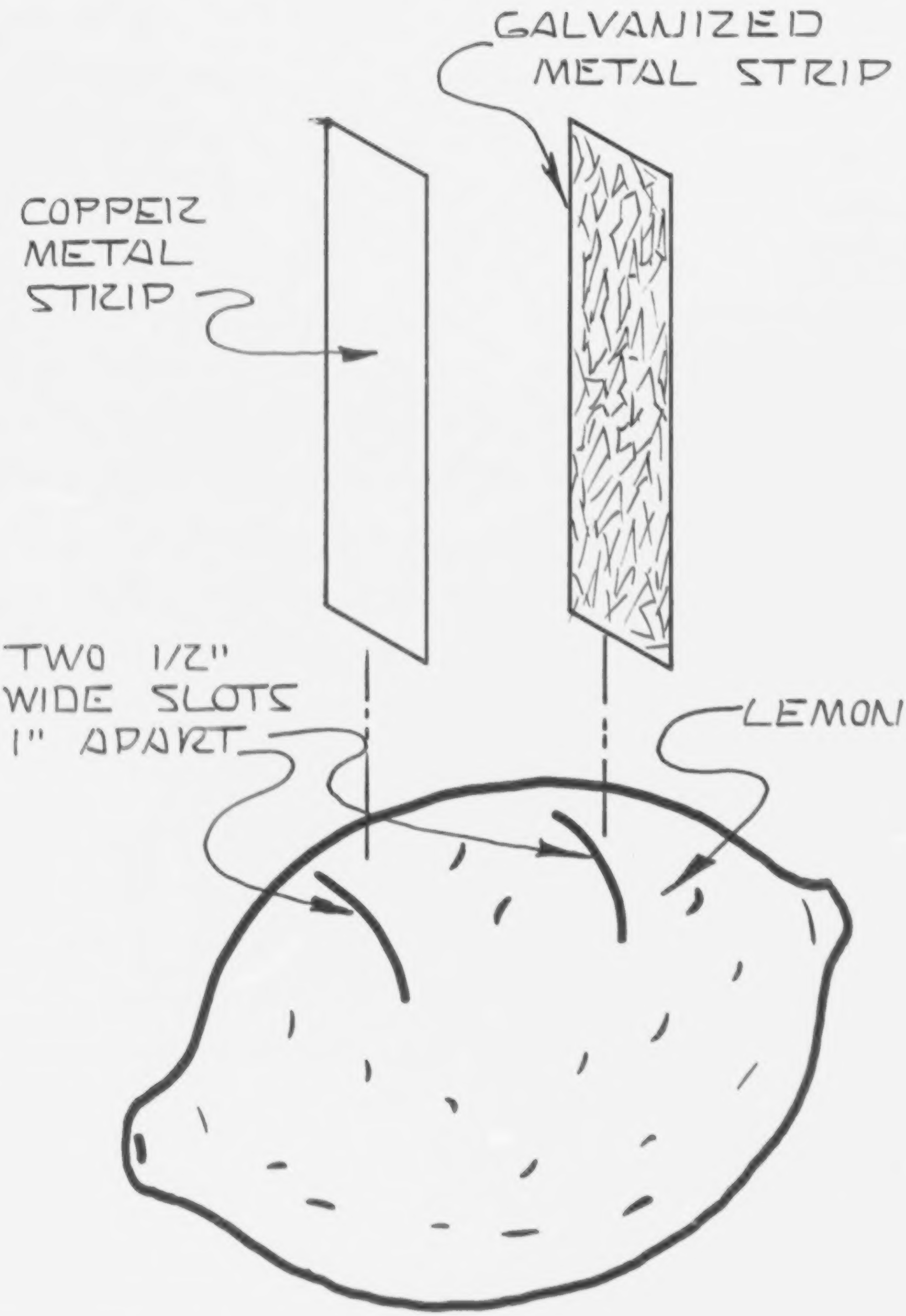


FIGURE 2-2, MAKING A CITRUS CELL

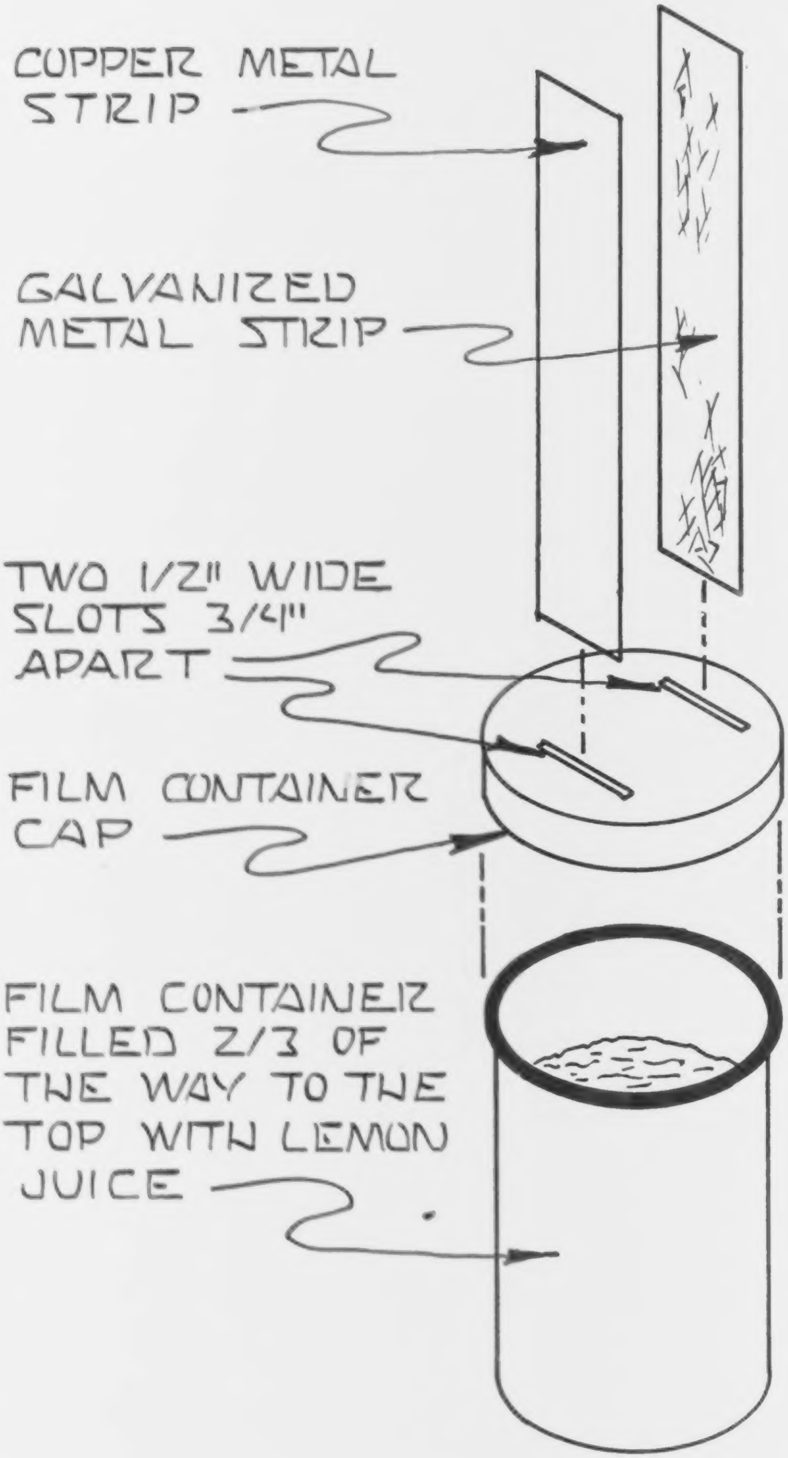

COPPER METAL STRIP
GALVANIZED METAL STRIP
TWO 1/2" WIDE SLOTS 3/4" APART
FILM CONTAINER CAP
FILM CONTAINER FILLED 2/3 OF THE WAY TO THE TOP WITH LEMON JUICE

FIGURE 2-3. MAKING A SIMPLE CELL

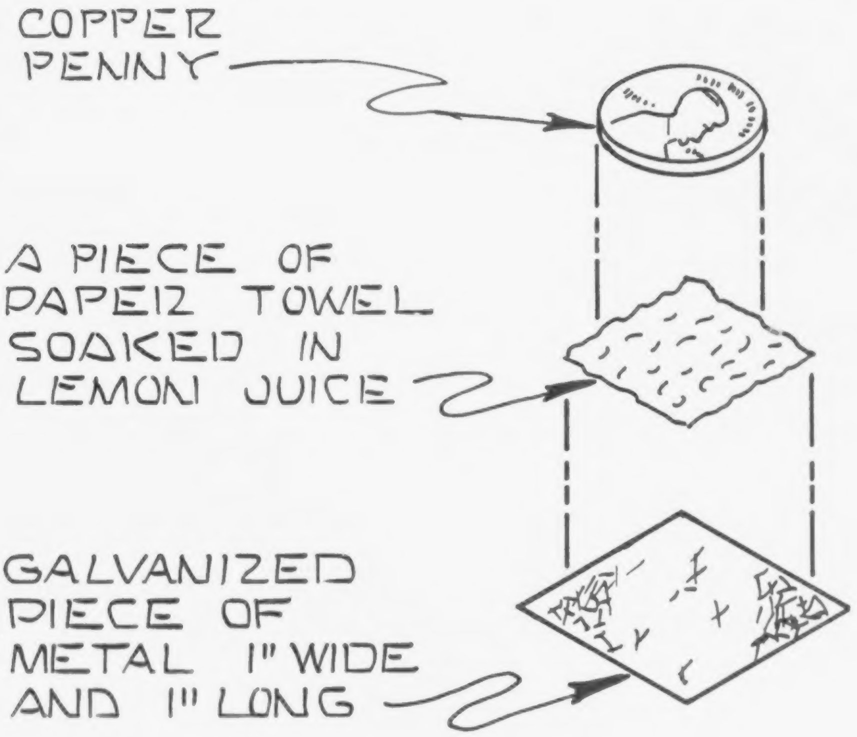
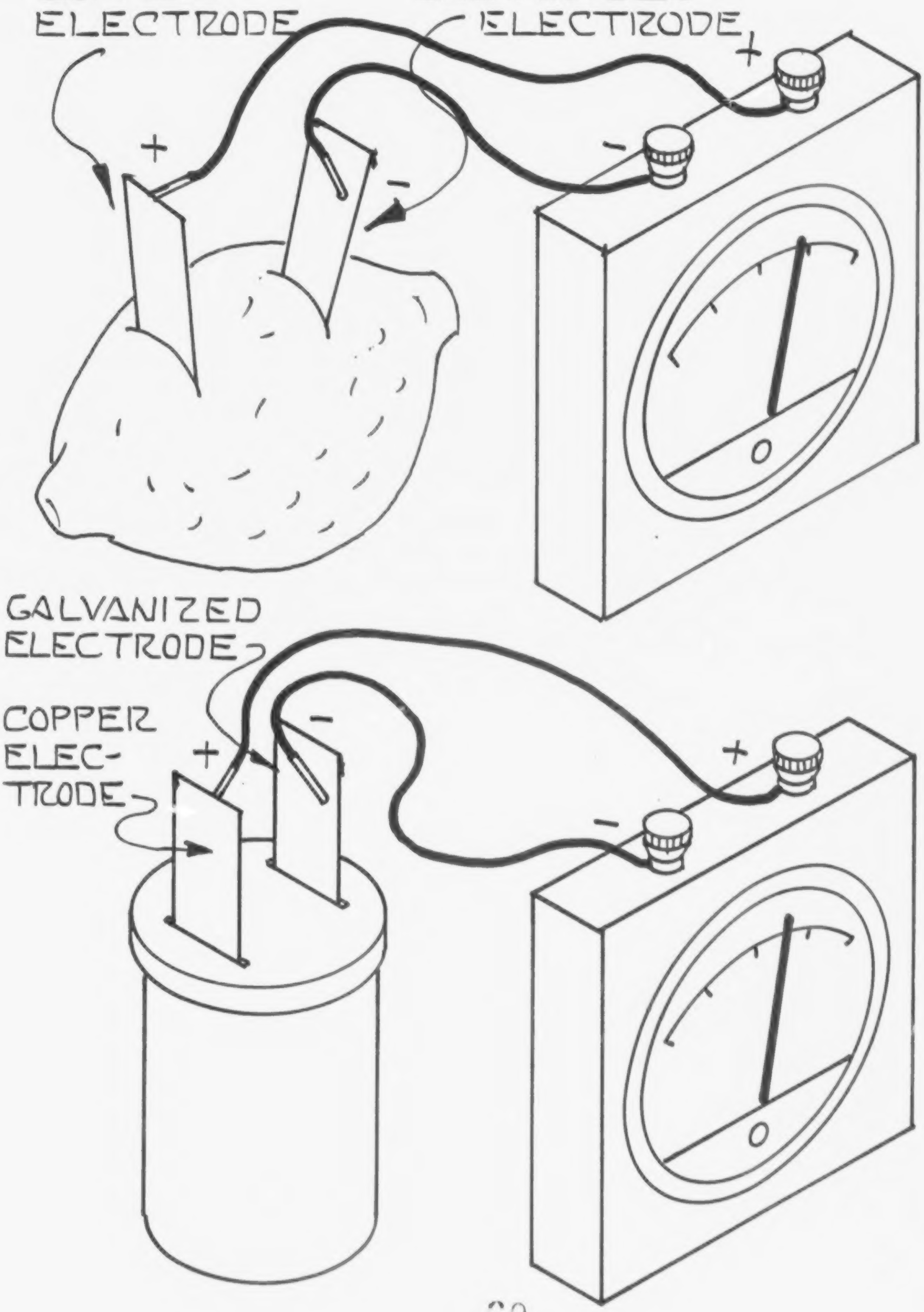
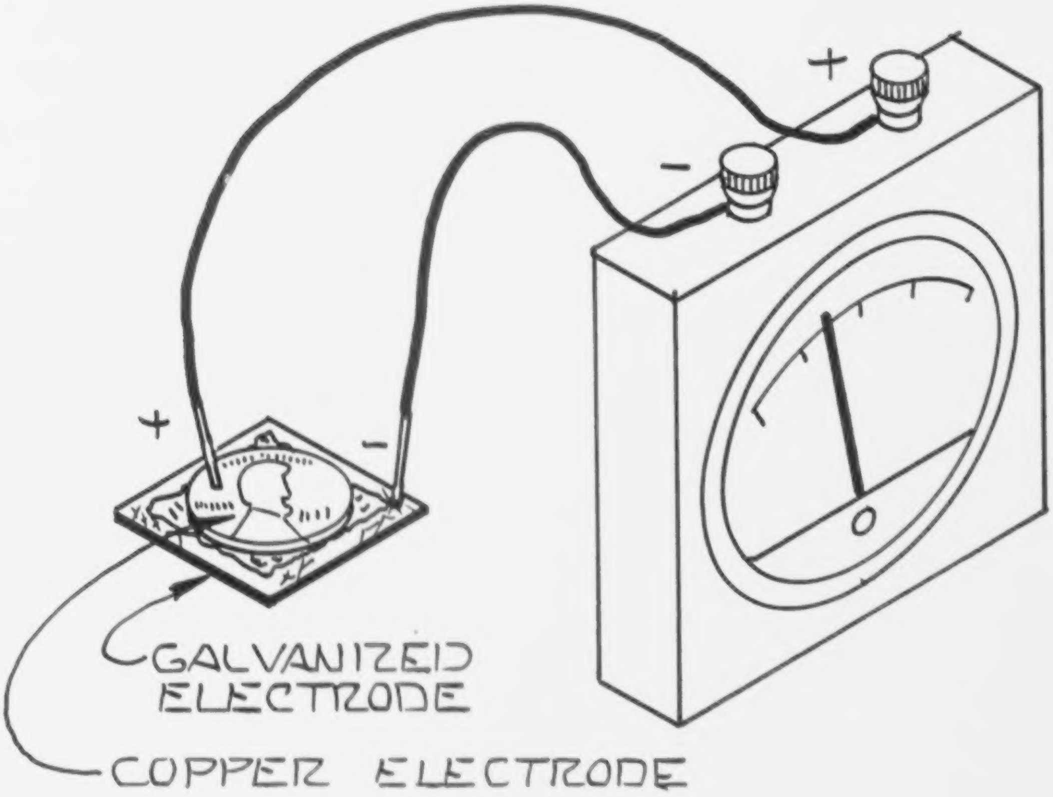

COPPER PENNY
A PIECE OF PAPER TOWEL SOAKED IN LEMON JUICE
GALVANIZED PIECE OF METAL 1" WIDE AND 1" LONG

FIGURE 2-4. MAKING A PENNY CELL

FIGURE 2-5. TESTING A CELL




+
−
+
−
GALVANIZED ELECTRODE
COPPER ELECTRODE
0

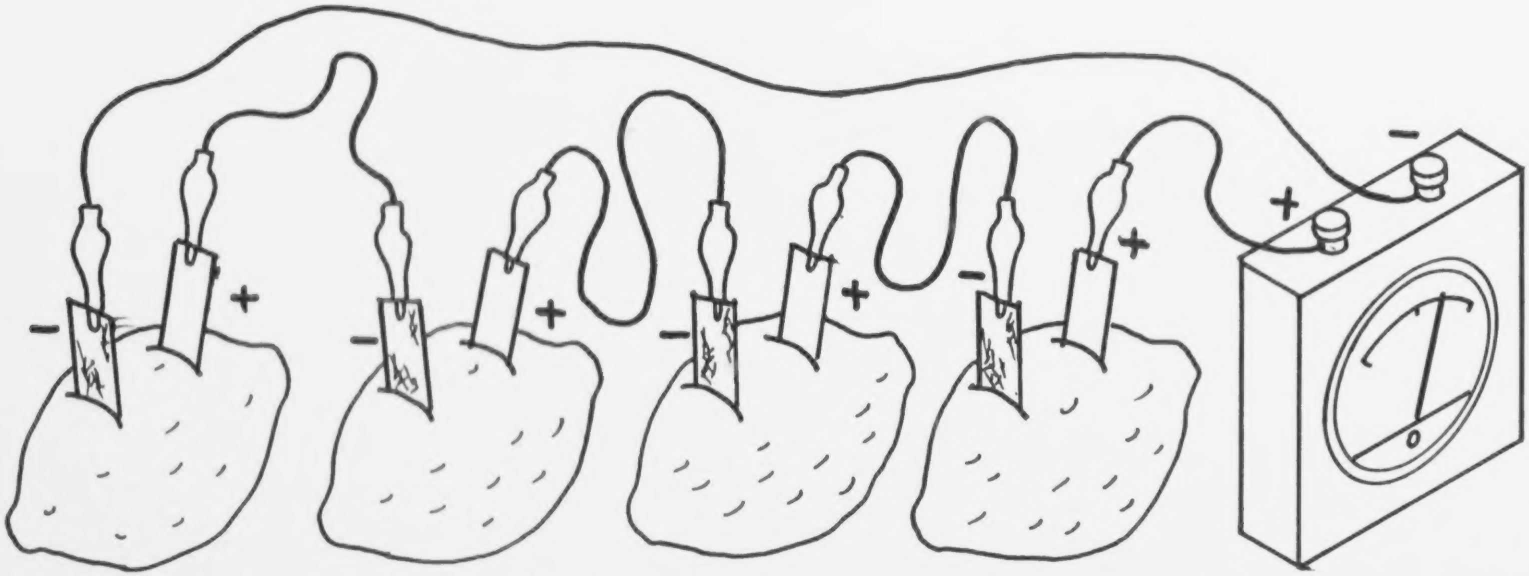


FIGURE 2-6. CONNECTING CELLS IN SERIES

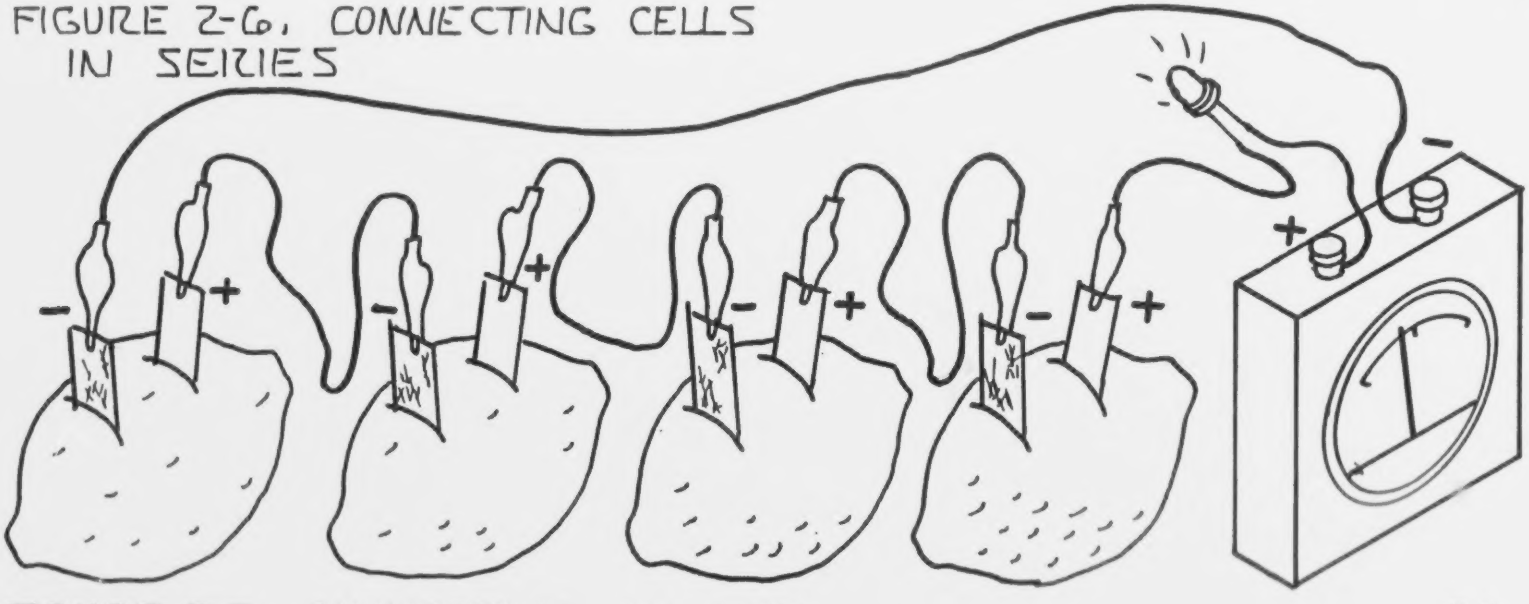


FIGURE 2-7. CONNECTING AN LED

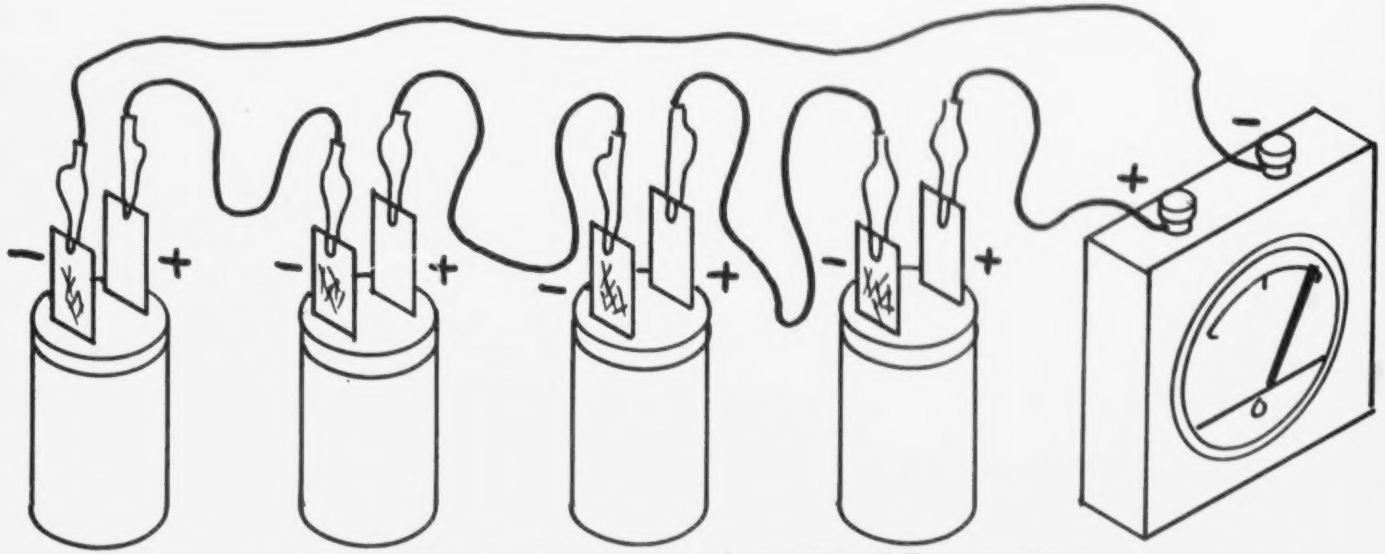


FIGURE 2-6, CONNECTING CELLS IN SERIES

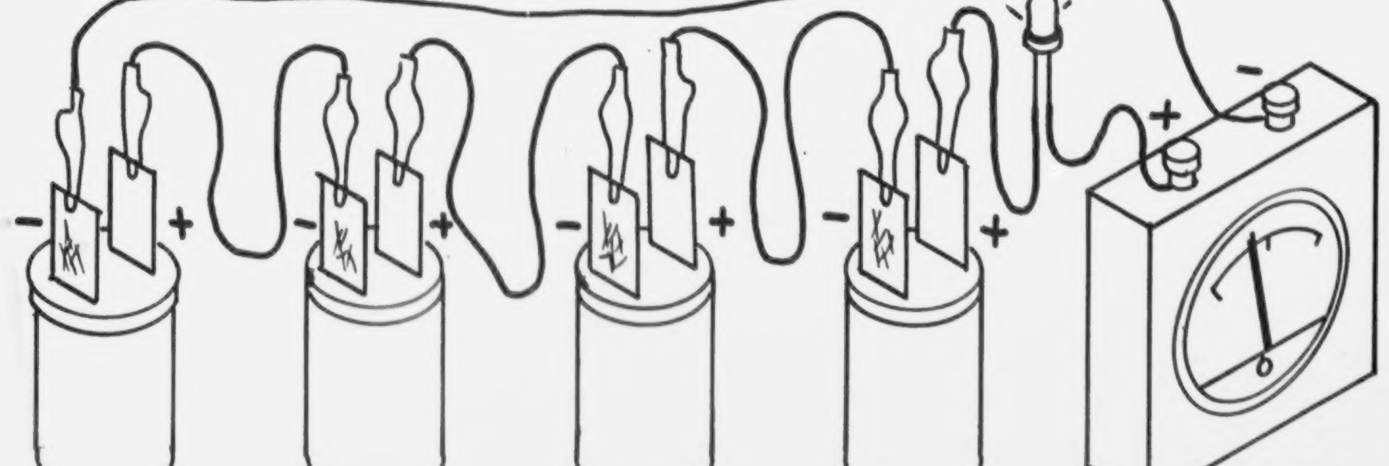


FIGURE 2-7. CONNECTING AN LED

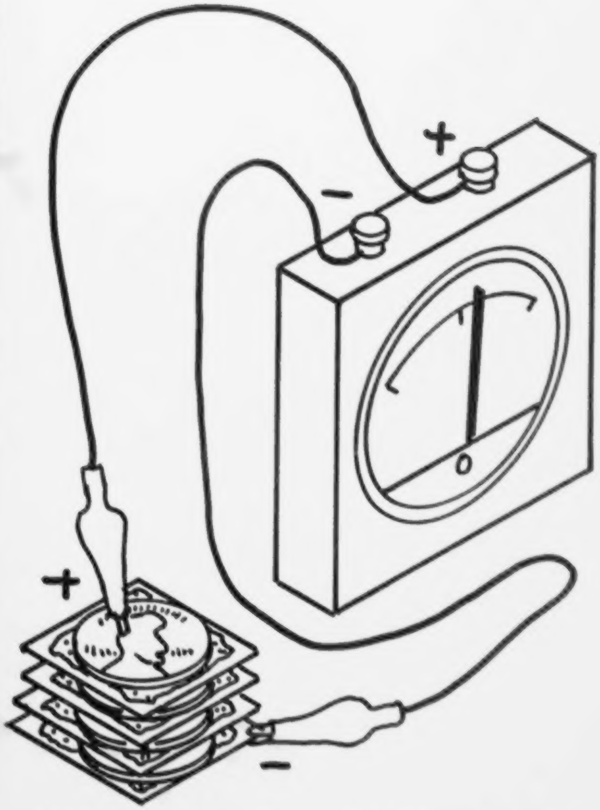


FIGURE 2-6. CONNECTING CELLS IN SERIES

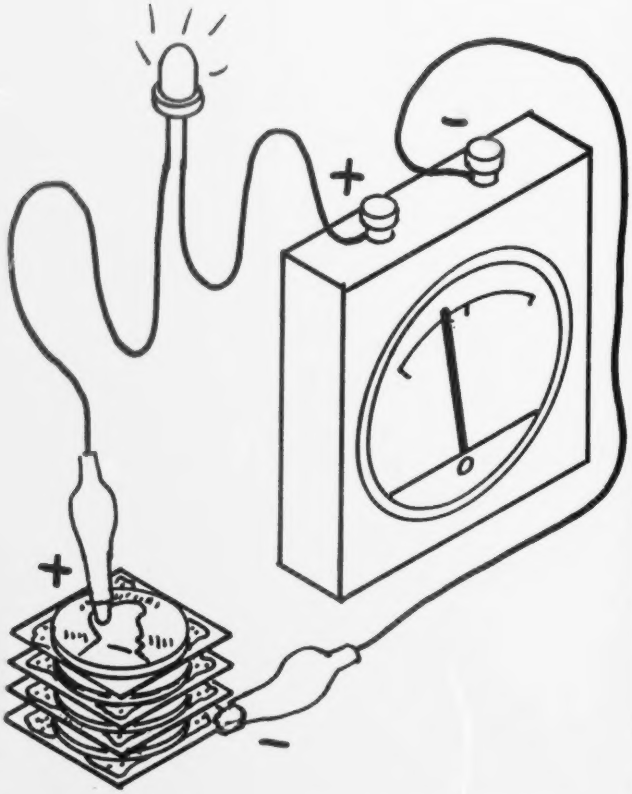


FIGURE 2-7. CONNECTING AN LED

MAKING AND TESTING A GENERATOR

The basic elements needed to make a generator are a coiled conductor, a magnetic field, and motion. You can make a coil with magnetic wire, a magnet can be used to provide the magnetic field, and you can provide the motion. In this lab activity, you will make and test a generator. In addition, you will experiment with a small generator.

Making and Testing an Electromagnetic Generator

1. To make and test a simple generator, you will need:

    * 1 plastic drinking straw
    * 30 feet of gauge magnet wire
    * 1 steel nail
    * 1 magnet
    * 1 pair of scissors
    * 1 microamp meter
    * 1 piece of fine sandpaper

2. Cut a 2" section off the drinking straw with a pair of scissors. Leaving a 3" lead, wind the wire around the straw. Try to make each turn as neat as possible. Leave a 3" lead at the end of the wire (see Figure 2-8).

3. Insert the steel nail inside the straw. With a piece of fine sandpaper, remove the lacquer finish at the end of each lead. Connect the leads coming from the coil to a meter designed to measure microamperes.

4. Position the magnet so that the north and south poles are parallel with the coil. Move the magnet back and forth along the side of the coil. Try to read the meter. Describe what the meter is doing in the space below.

    ____

    ____

Testing a Small Generator

1. For the next part of the lab activity, you will need:

   * 1 hobby motor (generator)
   * 1 milliamp meter
   * 1 volt meter
   * 3 jumper leads
   * 1 LED

2. Connect a small hobby motor to a milliamp meter with jumper leads. Make sure you connect the positive lead from the meter to the positive terminal on the motor. Connect the negative lead from the meter to the negative terminal on the motor (see Figure 2-9). They are usually marked on the motor.

3. When the meter is connected, twist the shaft on the motor as fast as you can. Read the meter and record the current in the space below.

   __________ milliamps

4. Connect the motor to a volt meter. Twist the shaft on the motor as fast as you can. Read the meter and record the voltage produced in the space below.

   __________ volts

5. If you can produce about 4 milliamps and 1/2 a volt with your motor, try connecting it to an LED (see Figure 2-10). Twist the shaft as fast as you can and see if you can produce enough energy to light the LED.

6. Generators convert _____ energy into electrical energy. Circle the correct answer.

   A. mechanical
   B. radiant
   C. chemical
   D. thermal

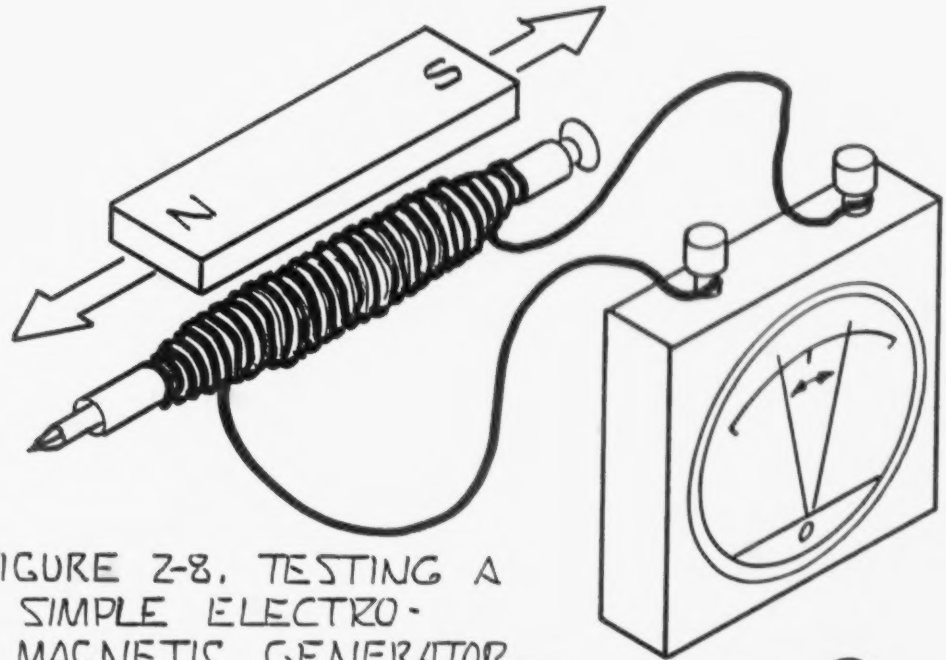


FIGURE 2-8. TESTING A SIMPLE ELECTRO-MAGNETIC GENERATOR

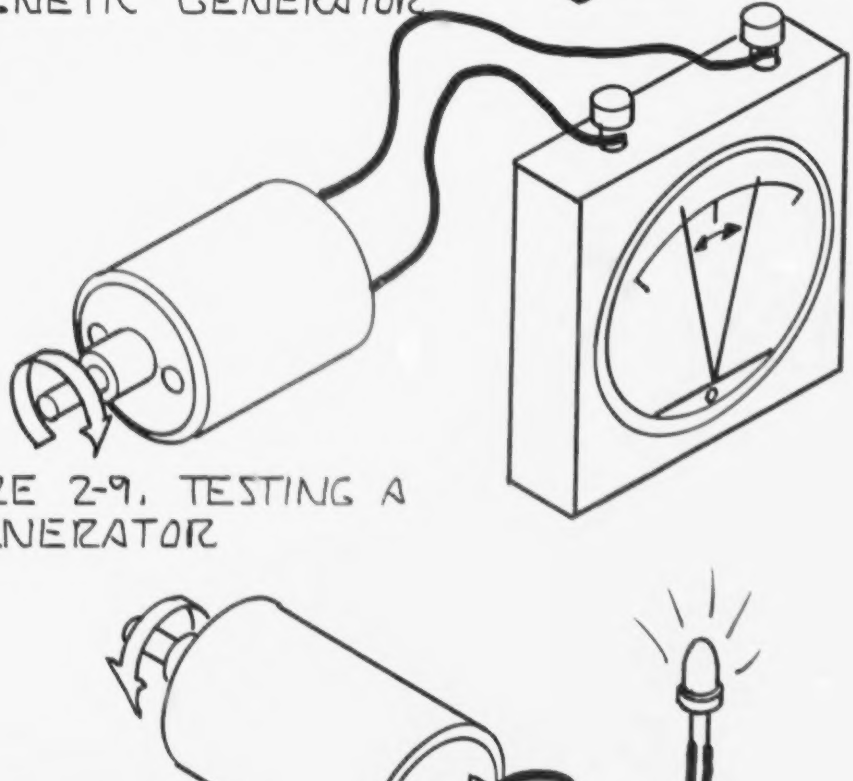


FIGURE 2-9. TESTING A GENERATOR

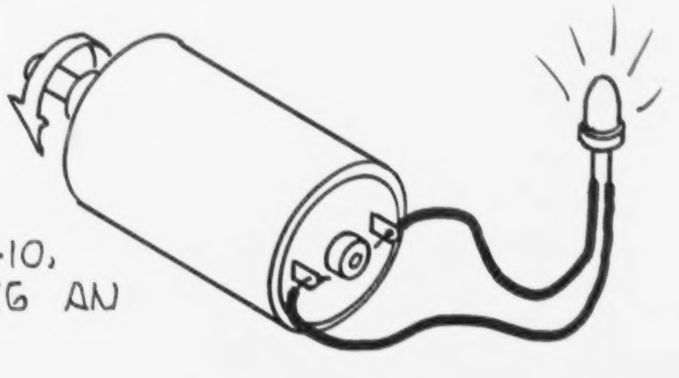


FIGURE 2-10. LIGHTING AN LED

PHOTOVOLTAIC CELLS

Photovoltaic cells convert radiant (light) energy into electrical energy. Unlike batteries and generators, photovoltaic cells have only been available since the mid 1950's. Recent innovations in photovoltaic technology have made them more affordable and efficient. They are used to power small electronic devices, generate electricity in remote areas, provide electricity for energy efficient homes, recharge batteries, and power the electronic equipment on board satellites. They have even been used to power an experimental airplane. New applications for photovoltaic devices are being developed all the time. During this lab activity, you will experiment with photovoltaic cells.

Testing a Photovoltaic Cell

1. For this lab activity, you will need:

   * 1 light source or access to sunlight
   * 1 photovoltaic array
   * 1 milliamp meter
   * 1 volt meter
   * 5 jumper leads
   * 1 LED

2. Locate your photovoltaic array in direct sunlight or about three feet away from a light source. Connect a voltmeter to one of the cells. Using jumper leads, connect the positive test lead to the positive terminal from the cell. Connect the negative test lead to the negative terminal from the same cell. Aim the photovoltaic cell directly at the sun or light source. Read the meter and record the voltage in the space provided below.

   __________ volts

3. Measure the current in the circuit with a milliamp meter. Connect the positive test lead to the positive terminal. Connect the negative test lead to the negative terminal. Read the meter and record the current in the space provided.

   __________ milliamps

Making and Testing a Photovoltaic Array

1. You probable noticed one photovoltaic cell does not produce a lot of volts or deliver a lot of current. Most applications require a photovoltaic array. A photovoltaic array is basically a collection of photovoltaic cells connected so they produce a higher voltage and/or more current. To increase the voltage produced, you need to connect the cells in series. When cells are connected in series, their total voltage equals the sum of their individual voltage. To connect cells in series, the positive terminal from the first cell needs to be connected to the negative terminal of the second cell. The positive terminal from the second cell needs to be connected to the negative terminal fo the third cell: This process is continued until all the cells are connected together. Using jumper leads, connect the photovoltaic cells in series (see Figure 2-11).

2. Measure the voltage produced by the array with a volt meter. Touch the positive from the meter to the positive terminal on the array. Touch the negative lead from the meter to the negative temrinal on the array. Read the meter and record the voltage in the space provided.

   ___________ volts

3. Connect an LED to your photovoltaic array (see Figure 2-12). Make sure the long lead on the LED is connected to the positive terminal. The LED should light. If it does not light, check all your connections.

4. Measure the current in the circuit with a milliamp meter. Connect the positive lead to the negative lead of the LED. Connect the negative lead to the negative terminal on the photovoltaic array. Read the meter and record the current in the space provided.

5. When cells are connected in series, the total voltage is equal to the sum of the _____ voltages.

6. When cells are connected in a series, the voltage in the circuit _____. Circle the correct answer.

   A. increases
   B. decreases
   C. stays the same

7. When cells are connected in series, the current in the circuit _____. Circle the correct answer.

   A. increases
   B. decreases
   C. stays the same

8. Photovoltaic cells convert _____ energy into electrical energy. Circle the correct answer.

   A. mechanical
   B. radiant
   C. chemical
   D. thermal

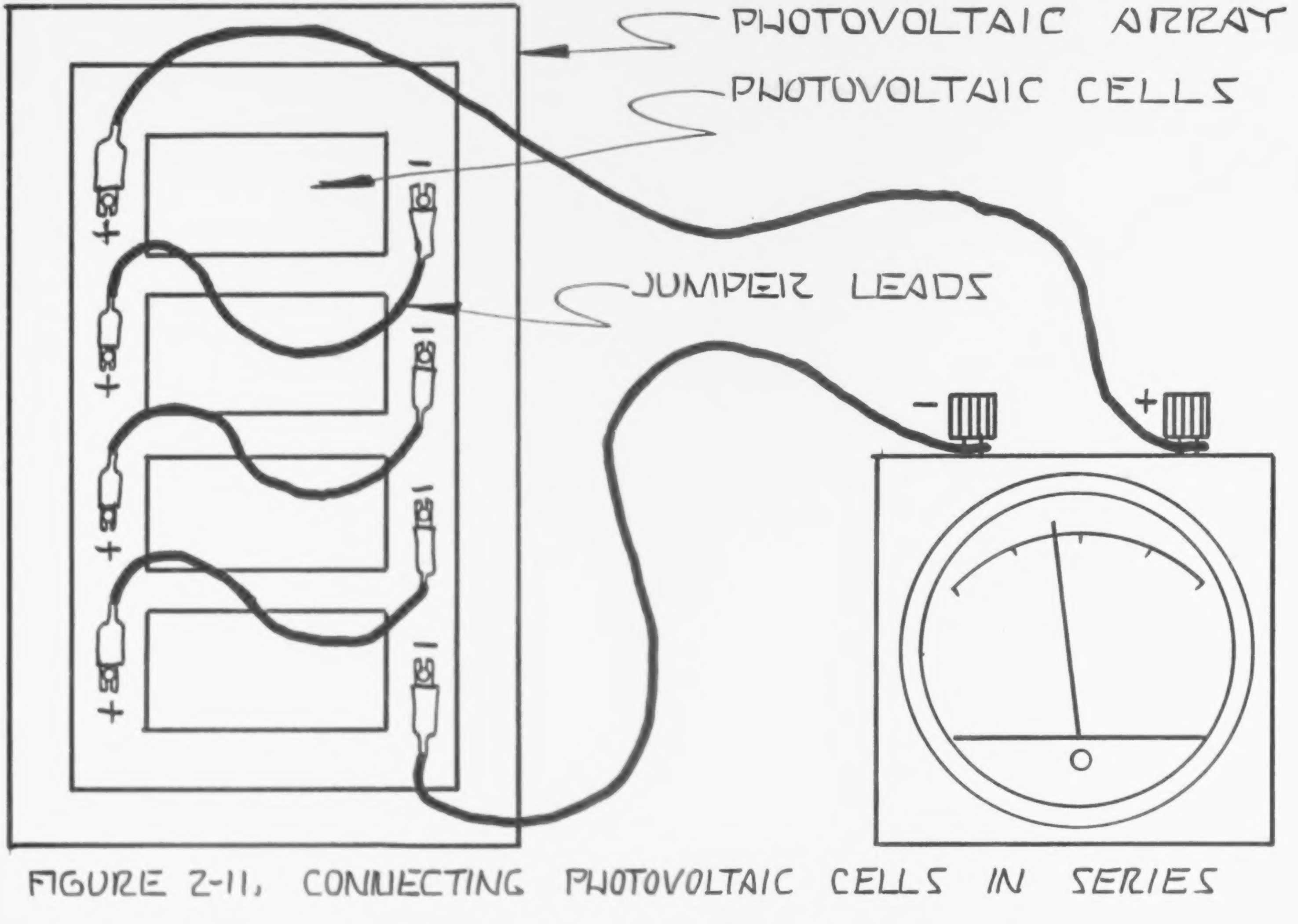


FIGURE 2-11, CONNECTING PHOTOVOLTAIC CELLS IN SERIES

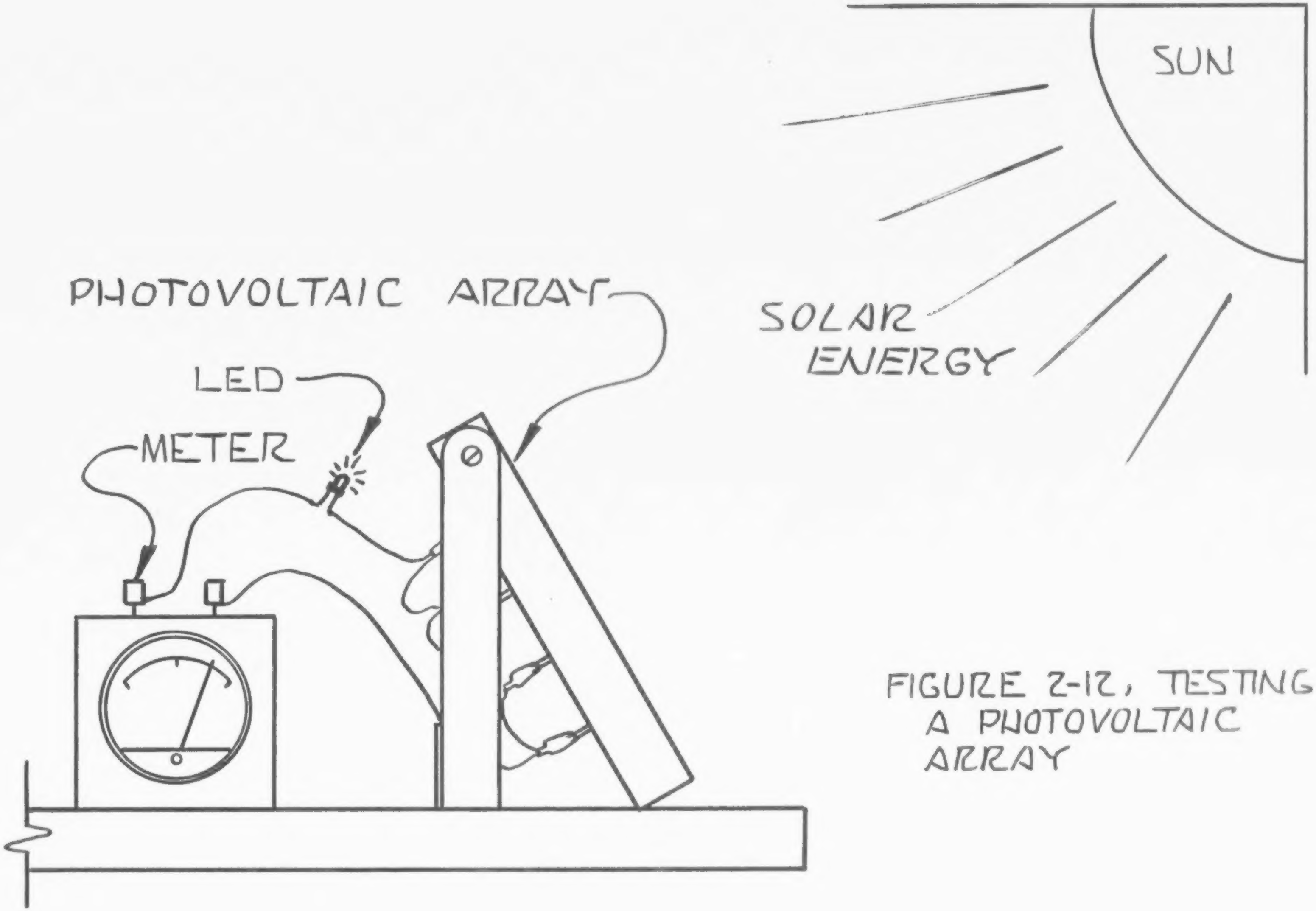
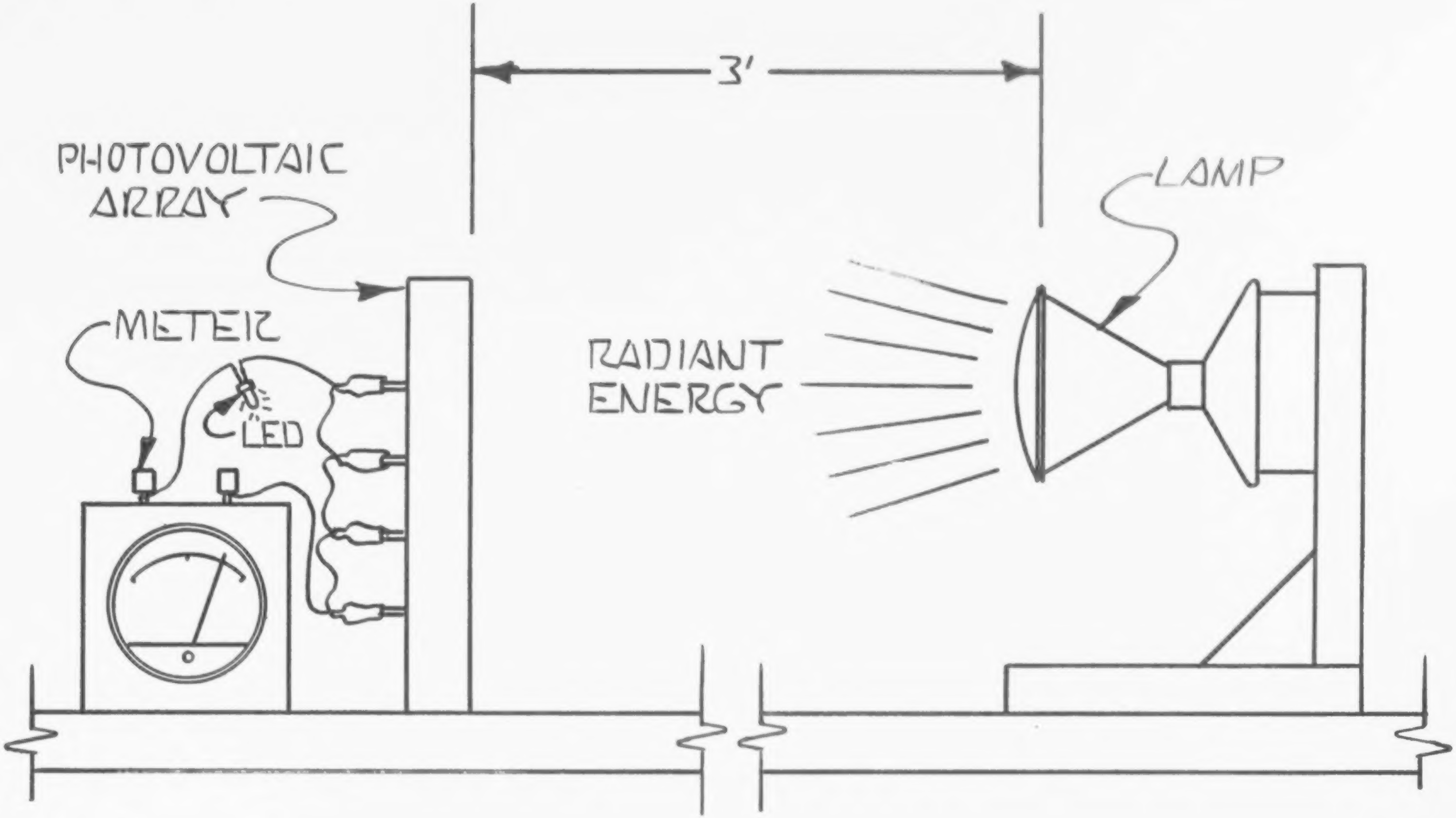


FIGURE 2-12, TESTING A PHOTOVOLTAIC ARRAY

FIGURE 2-13, TESTING A PHOTOVOLTAIC ARRAY



THERMOCOUPLES

Thermocouples convert thermal (heat) energy into electrical energy. They are commonly used to monitor, measure, and control thermal energy systems. For example, thermocouples are used to measure the temperature of molten metal in foundries. They are commonly used to trigger shut off valves on gas furnaces and water heaters if the pilot light goes out. During the lab activity you will be experimenting with a thermocouple for a gas furnace or hot water heater.

Testing a Thermocouple

1. For this lab activity, you will need:

   * 1 thermocouple
   * 1 candle
   * 1 match
   * 1 volt meter
   * 1 microamp meter
   * 2 jumper leads

2. Connect the volt meter to the thermocouple (see Figure 2-14). Use a jumper lead to connect the positive meter lead to the copper tubing on the thermocouple. Use a second jumper lead to connect the negative meter lead to the conductor at the end of the copper tubing.

3. Locate the candle away from flammable materials. Light the candle and place the tip of the thermocouple in the flame. Read the meter and record the output voltage in the space provided.

   ____________ volts

4. Measure the current in the circuit with a microamp meter. Connect the positive meter lead to the copper tubing coming from the thermocouple. Connect the negative meter lead to the conductor at the end of the tubing. Read the meter and record the current in the space provided.

   ___________ microamps

5. Thermocouples convert _____ energy into electrical energy. Circle the correct answer.

   A. mechanical
   B. radiant
   C. chemical
   D. thermal

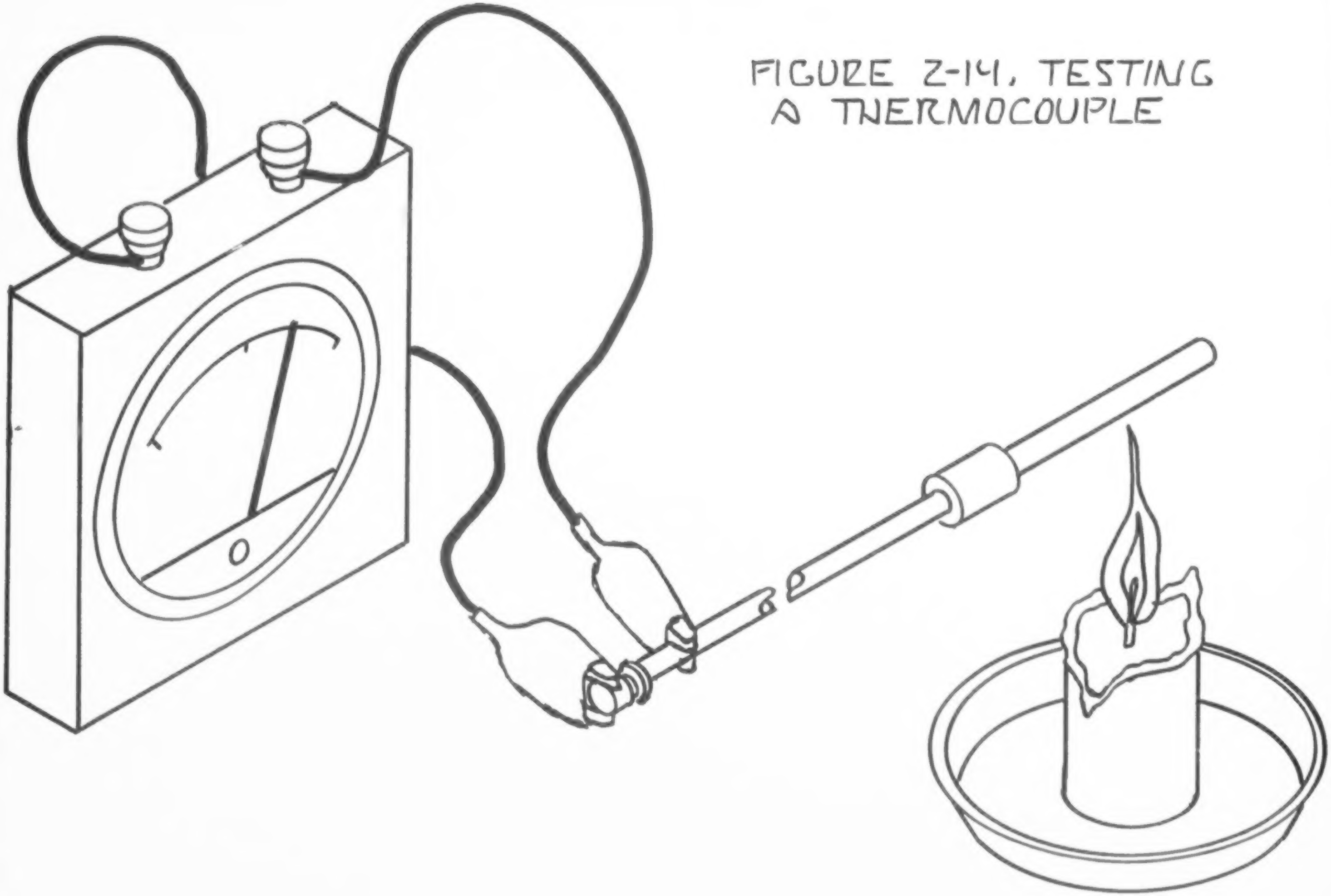


FIGURE 2-14. TESTING A THERMOCOUPLE

Unit: Exploring Electricity/Electronics Lesson 3: Output Transducers and Control Devices

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for an output transducer -identify four examples of output transducers. -complete flow charts illustrating the energy conversion process for light bulbs, motors, heating elements, and piezo electric buzzers. -identify a definition for a control device. -identify four basic examples of control devices. -identify how given control devices are actuated.	A. Output transducers and control devices. 1. Output transducers a. use electrical energy to perform work b. convert electrical energy into other forms of energy 2. Basic output transducers a. lightbulbs b. electric motors c. heating elements d. piezo electric buzzers e. meter movements f. LED's g. speakers h. CRT's 3. Output transducers convert electrical energy to: a. radiant energy b. thermal energy c. mechanical energy d. sound energy	A. Teacher Guided Discussion 1. Ask students to identify electrical devices that perform work. Discuss how each device converts electrical energy into a more useful form of energy. 2. Using OT #3-1, discuss the definition for an output transducer. 3. Using OT #3-2, list examples of output transducers. 4. Using OT #3-3, discuss how electricity can be converted into other forms of energy. 5. Using OT #3-4 through OT #3-7, discuss a variety of output transducers in detail. 6. Using OT #3-8, discuss the definition for a control device.	

4. Control devices
   a. start or stop electron flow by opening or closing the circuit
   b. regulate electron flow in a circuit
5. Basic control devices
   a. switches
   b. thermostats
   c. photocells
   d. variable resisters
   e. fuses
   f. circuit breakers
6. Types of actuation
   a. mechanical
   b. thermal
   c. radiant
   d. sound

7. Using OT #3-9, list examples of control devices.
8. Using OT #3-10, discuss how control devices can be actuated.
9. Using OT #3-11, discuss how various control devices control current flow.

B. Following a demonstration, in a lab activity, students will be able to:
- use schematic drawings and electrical components to build working circuits.
- describe the relationship between voltage measured at the power supply and voltage measured at the output transducer in a circuit.
- describe how the control device in a circuit regulates current.
- describe how the control device in a circuit is actuated.
- describe the energy conversion process in a circuit.

B. Making and testing electrical circuits.
1. Making circuits
   a. light circuit
   b. temperature control circuit
   c. light meter circuit
   d. alarm circuit
   e. variable speed electric motor circuit
2. Testing circuits
   a. measuring voltage rise
   b. measuring voltage drops
   c. measuring current
   d. completing a lab sheet

B. Learning Activities
1. Explain how to use a schematic drawing to build a working circuit.
2. Demonstrate how to measure voltage rise, voltage drop, and current in a circuit using a meter(s).
3. Provide students with HO #3-1 through HO #3-6. Divide the class into groups of three to four students.
4. Assign each group a work station and have them complete the lab activity.
5. When students have finished the lab, rotate them to the next work station.
6. Circulate around the room and provide individual instruction as needed.
7. When students have finished all five lab activities, ask students questions about the characteristics of each circuit.
8. Collect and evaluate the lab sheets for all five lab activities.

OUTPUT TRANSDUCERS AND CONTROL DEVICES

Preparation Hints:

1. Review the materials provided, duplicate HO #3-1 through HO #3-6, and prepare the transparencies needed to present this lesson.

2. During the lab activity, your students will be making and testing a variety of circuits. Prior to implementing this lesson, you will need to collect and organize the materials listed in the handouts. The output transducers and control devices listed in the handouts can be purchased from most electronics stores or venders.

3. Prior to implementing this lesson, consider mounting electronic components on fixtures similar to those illustrated in the handouts. Mounting the components on fixtures will make them easier to handle and will extend their life considerably.

4. Prior to implementing this lesson, consider performing each of the lab activities. Making and testing each circuit will help you test your materials, anticipate problems, and develop strategies for assuring student success.

Content Presentation Hints:

1. Show students a variety of output transducers and control devices. Your examples could include things like LED's, liquid crystal displays, microswitches, read switches, thermostats from automobile engines, heating elements, and circuit breakers.

2. Consider showing a film or video tape featuring electrical systems, control devices, and/or output transducers.

3. Ask students to list a variety of electrical systems at work in your laboratory. Discuss each electrical system in terms of its energy transducer, control device, output transducer, and conductor path. Discuss how energy is converted from one form to another in each electrical system.

Learning Activity Hints:

1. If time is limited, divide your class into groups of three to four students and assign each group a circuit to build and test. When students have finished building and testing their circuit, have each group explain and demonstrate how their circuit works to the rest of the class. During their presentations, students could describe the energy conversion process, explain how the control device regulates current, and identify how the control device is actuated.

2. If time permits, allow students to modify their circuit using new control devices and output transducers. For example, students could build a temperature controlled fan using a thermostat and a motor. Students could use a photocell to turn a light on and off. Lastly, students could use a pin or mercury switch to control a piezo electric buzzer.

3. When students have finished building and testing a given circuit, consider asking students to draw a flowchart illustrating the circuit's basic components and the energy conversion process. Refer to Figure 3-1 for an example flowchart.

4. When students have finished the lab activities, consider displaying their electrical circuits in a location where the rest of the school community can see the results of their circuit analysis activities.

OT #3-1

Output transducers:

* use electrical energy to perform work

* convert electrical energy into other forms of energy

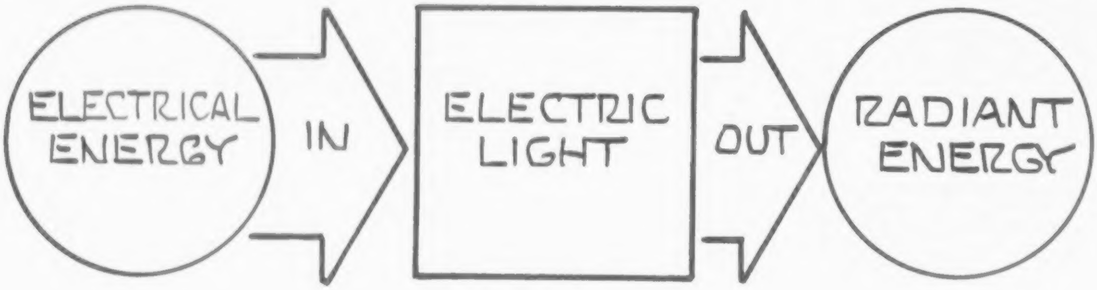
OT #3-2

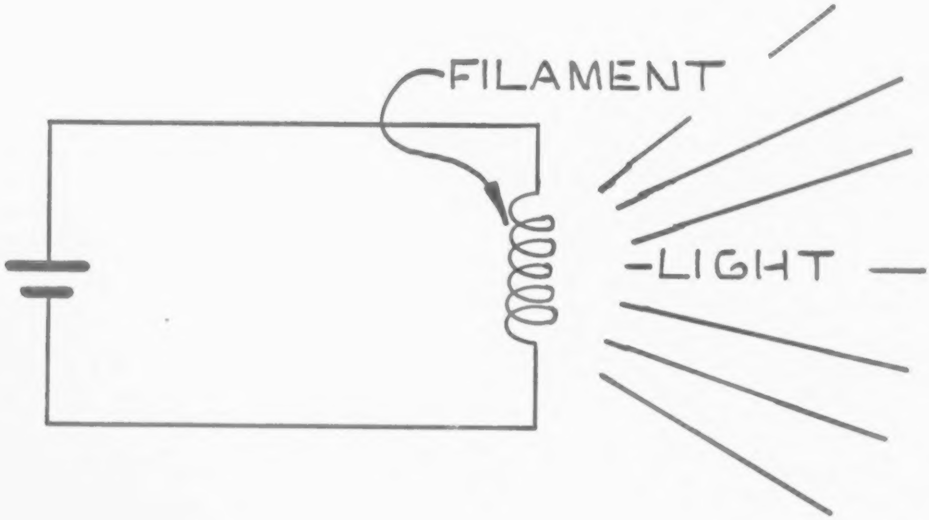
Basic output transducers:

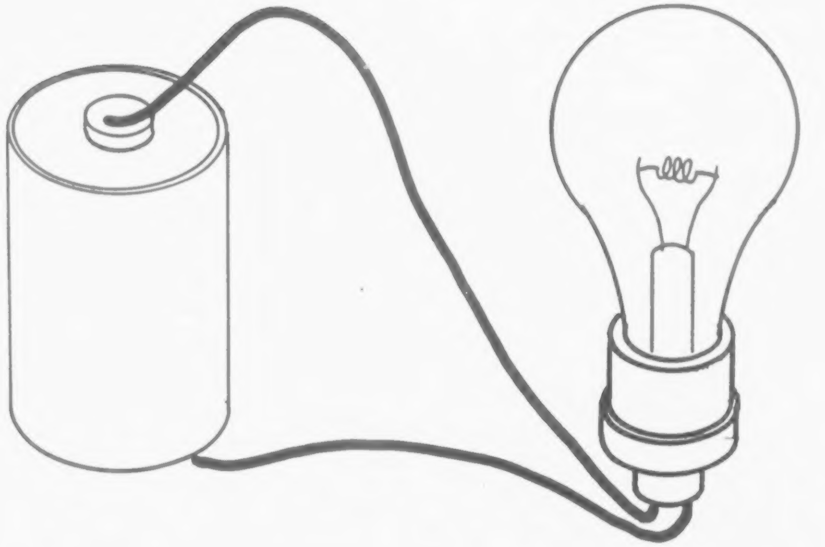
* lightbulbs
* electric motors
* heating elements
* piezo electric buzzers
* meter movements
* LED's
* speakers
* CRT's

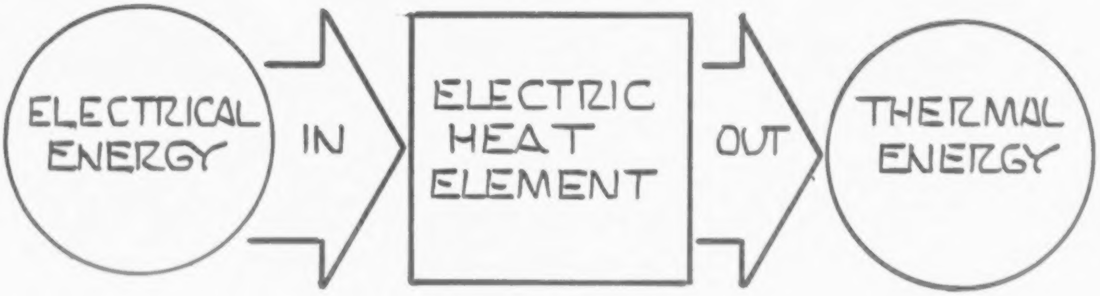
Output transducers convert electrical energy to:

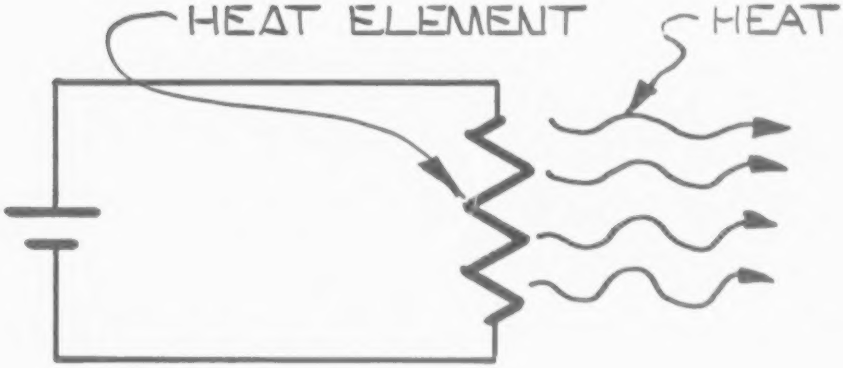
* radiant energy
* thermal energy
* mechanical energy
* sound energy

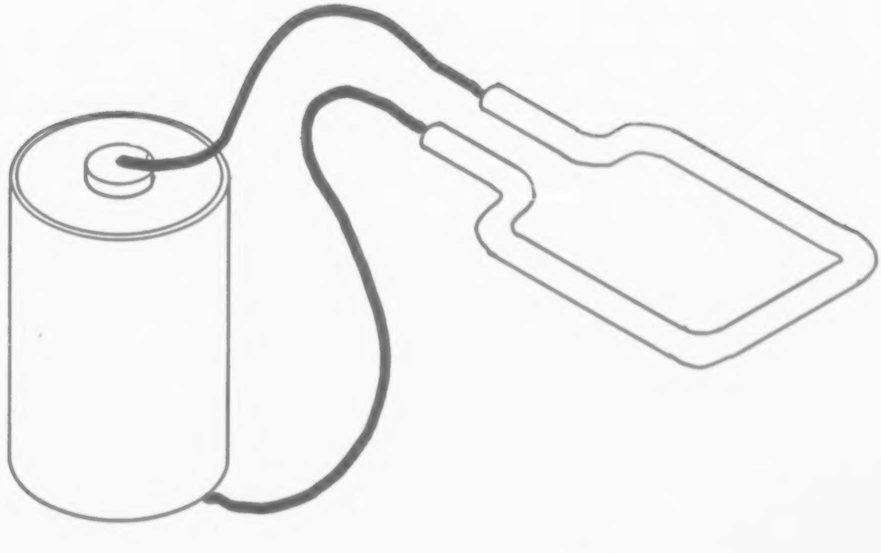

ELECTRICAL ENERGY
IN
ELECTRIC LIGHT
OUT
RADIANT ENERGY


FILAMENT
LIGHT

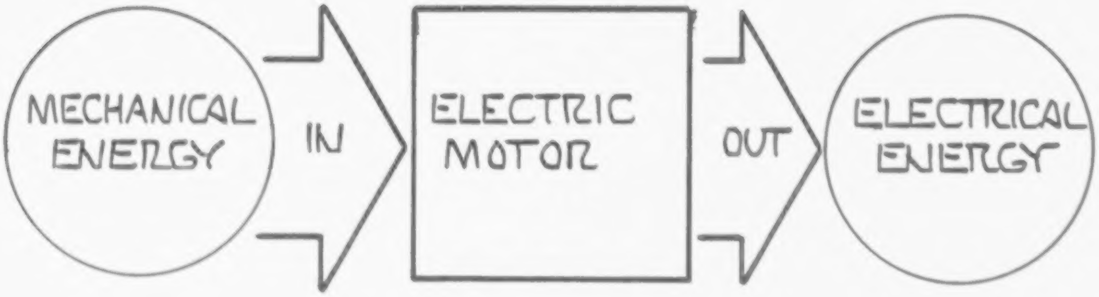


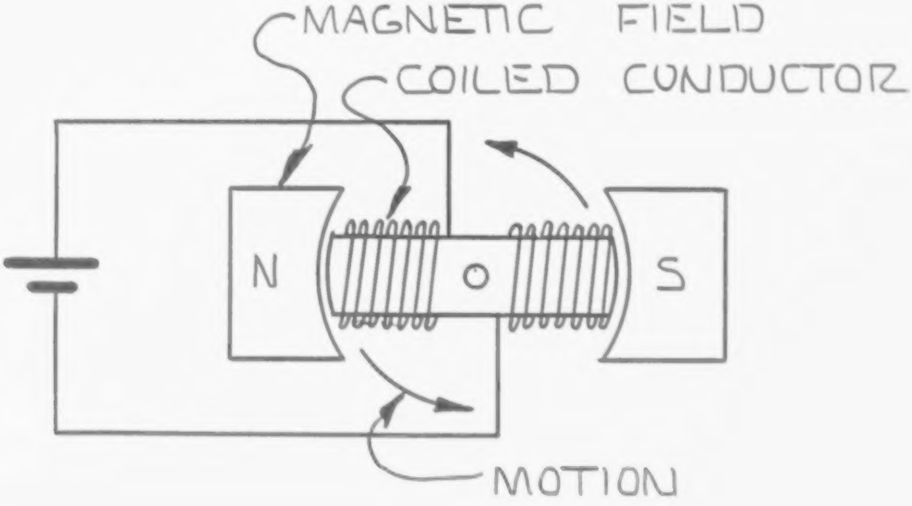

ELECTRICAL ENERGY
IN
ELECTRIC HEAT ELEMENT
OUT
THERMAL ENERGY

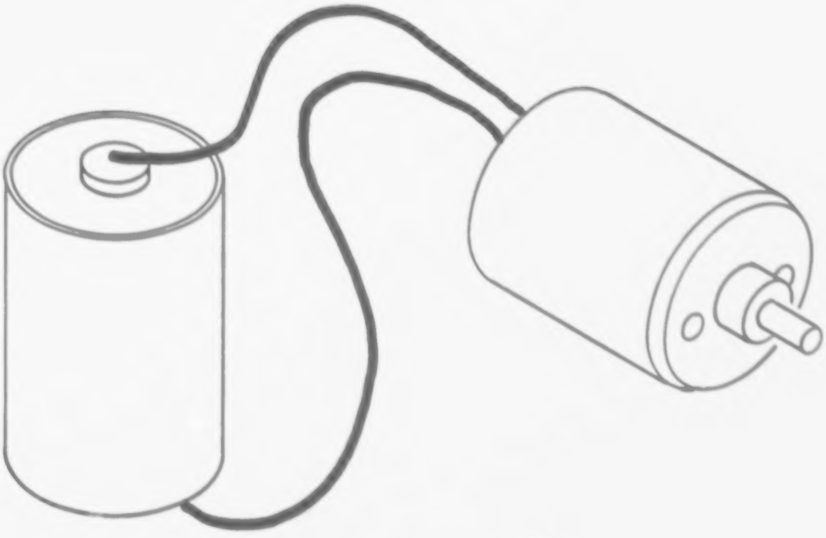

HEAT ELEMENT
HEAT



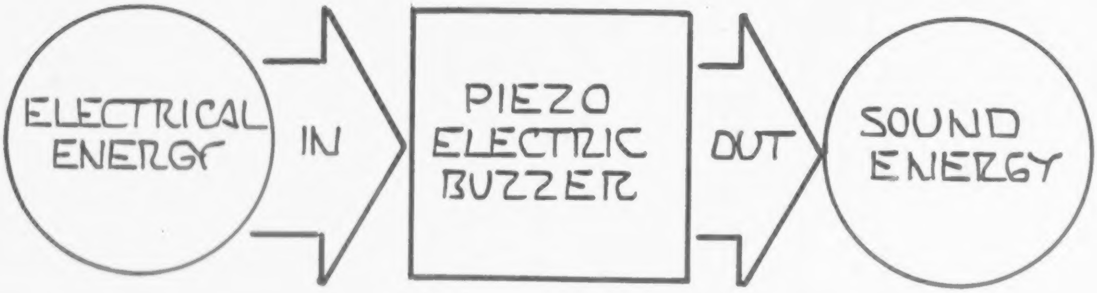
OT #3-6

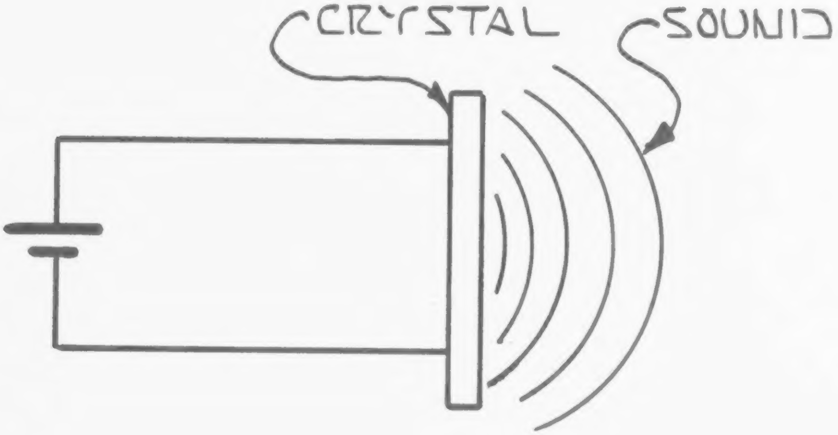

MECHANICAL ENERGY
IN
ELECTRIC MOTOR
OUT
ELECTRICAL ENERGY

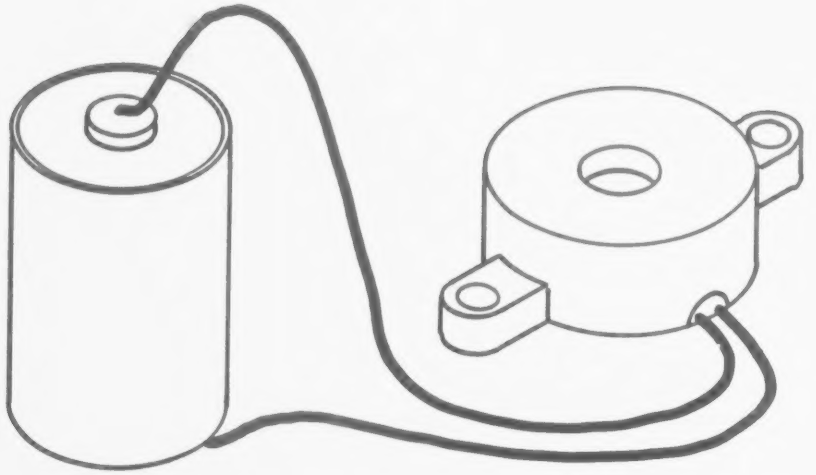

MAGNETIC FIELD
COILED CONDUCTOR
N
S
MOTION



OT #3-7


ELECTRICAL ENERGY
IN
PIEZO ELECTRIC BUZZER
OUT
SOUND ENERGY


CRYSTAL
SOUND



OT #3-8

Control devices:

* start or stop electron flow by opening or closing the circuit.

* regulate electron flow in a circuit.

OT #3-9

Basic control devices:

* switches

* thermostats

* photocells

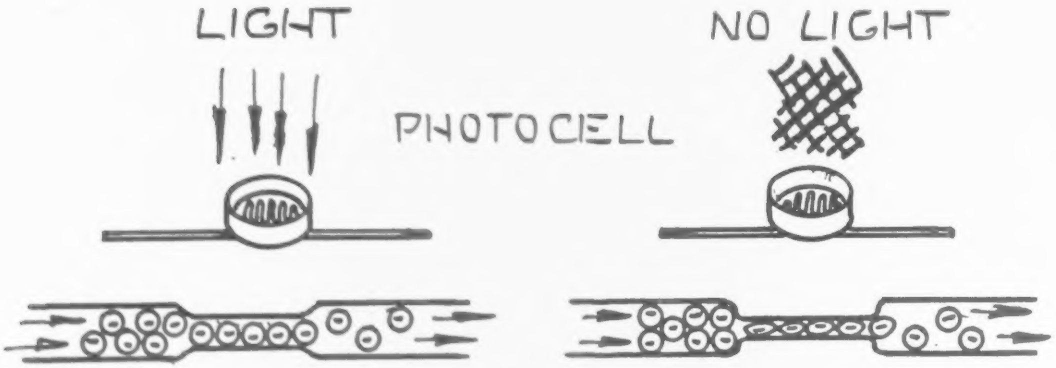
* variable resisters

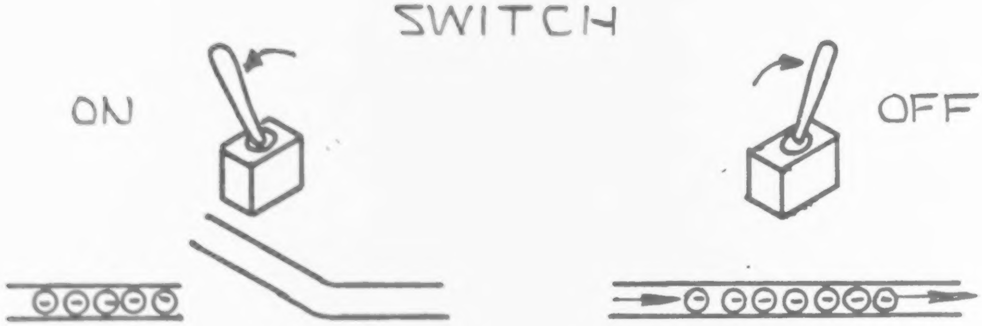
* fuses

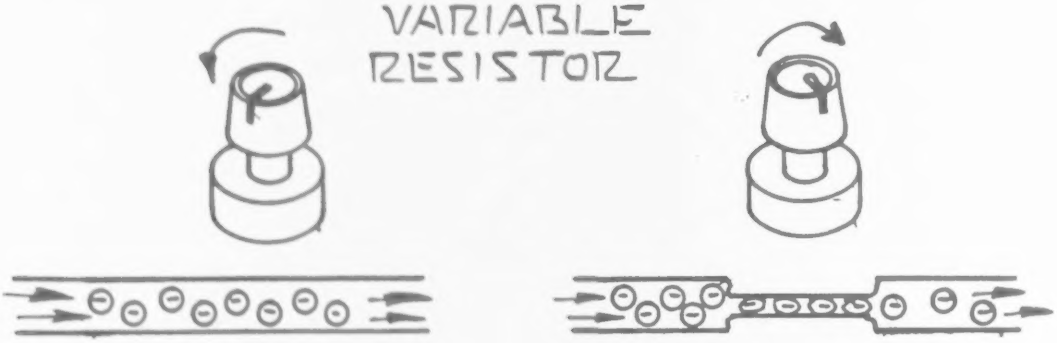
Types of actuation:

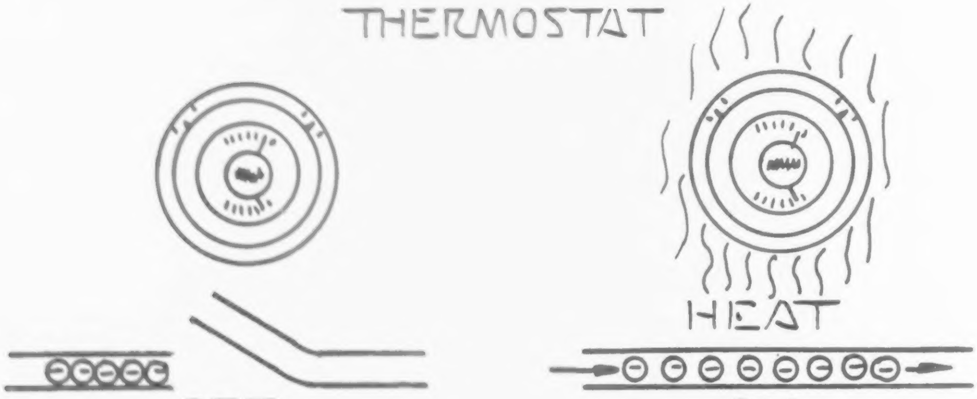
- * mechanical
- * thermal
- * radiant
- * sound

OT #3-11


LIGHT
NO LIGHT
PHOTOCELL


SWITCH
ON
OFF


VARIABLE
RESISTOR


THERMOSTAT
HEAT
OFF
ON

OUTPUT TRANSDUCERS AND CONTROL DEVICES

Discussion:

A simple electrical circuit includes an energy transducer, a conductor path, an output transducer, and a control device. The energy transducer converts chemical, mechanical, radiant, or thermal energy into electrical energy. Electrons carry the electrical energy through the conductor path in the form of current. In order to perform work, the energy being carried by the electrons needs to be harnessed and converted into a more useful form of energy.

Output transducers are devices that use electrical energy to perform work. In order to perform work, they convert electrical energy into radiant (light), thermal (heat), mechanical (motion), or sound energy. Common examples of output transducers include things like light bulbs, electrical motors, heating elements, and buzzers.

Light bulbs convert electrical energy into radiant (light) energy. Electrical current travels through a thin wire called a filament.. The filament is enclosed in a vacuum or surrounded by a gas. The filament restricts the flow of electrons and it becomes white hot. The lack of oxygen inside the bulb prevents it from burning up. The glow from the white hot filament can be used to light an area.

Electrical motors use magnetism to cnvert electrical energy into mechanical energy. Electrical current is passed through a coil called the armature. The armature is placed between north and south poles of a magnet. Since current is flowing through the armature, it produces a magnetic field. The magnetic field produced by the armature and that produced by the magnets attract each other and the armature turns. As the armature rotates past the magnets, the current is reversed and magnetic poles repel each other. The attraction and repulsion of magnetic fields cause the armature to rotate. Electrical motors are used for things like circulating air in buildings, starting automobile engines, and driving the machines in your laboratory.

Heating elements use electrical resistance to convert electrical energy to thermal (heat) energy. If you press your hands together and rub them back and forth as fast as you can, you will produce heat. This heat is due to friction. Friction is the product of resistance. In electricity, resistance is opposition to current flow. When a material with high resistance is put in a circuit, there is a lot of electrical friction when the electrons pass through the material. This electrical friction produces heat. Electric space heaters, toasters, hair dryers, clothes dryers, and ranges all use electrical resistance to produce heat.

A piezo electric buzzer converts electrical energy into sound energy. When a voltage is applied across a special crystal material, it will distort. If the voltage is applied in controlled pulses, the crystal will vibrate back and forth. These vibrations produce sound waves we can hear. Piezo electric buzzers are commonly used for the alarm on electronic watches.

If you want to be able to turn a light on or off, or be able to control the speed of a motor, the circuit needs to include a control device. Control devices allow you to start, stop, and/or regulate current flow in a circuit. Examples of basic control devices include switches, thermostats, photocells, variable resistors, and fuses.

Control devices can be actuated a variety of ways. Most control devices are actuated mechanically. However, some are actuated with heat, light, or a magnetic field. For example, the switches you turn on and off manually are mechanically activated. Outdoor lights that turn on by themselves with the sun goes down are controlled by a light activated switch. Burglar alarms often use switches that turn on and off with a magnet. The furnace in our home is controlled by a switch that turns on and off with changes in the room temperature.

Switches control the flow of electrons much the same way as a drawbridge controls traffic. When the bridge is down, traffic flows smoothly. When the bridge is up, the roadway is incomplete and cars cannot cross. When a switch is closed, current flows smoothly. When the switch is open, the conductor path is incomplete and current cannot flow.

Variable resistors regulate current flow by changing the resistance in a circuit. Variable resistors use conductors that resist the flow of electrons to control current in a circuit. When resistance (opposition to current flow) in a circuit is low, current flow is fast. When resistance in a circuit is high, current flow is slow. Most variable resistors are adjusted manually.

Photocells are resistors that change with light. When they are exposed to bright light their resistance decreases. When exposed to darkness, their resistance is high.

Thermostats use temperature sensitive materials to control current flow. For example, the thermostats used in many homes use two metal strips that form a switch. When they are cold, they touch, the circuit is closed, and the furnace will run until the house warms up. When the house does warm up, one of the metal strips will expand, the circuit will become open, and the furance will shut off.

Fuses use heat to protect a circuit from an overload. An overload occurs when the current in a wire becomes so great it becomes hot. There is often a danger of fire when an overload occurs. To prevent an overload, many circuits include a control device called a fuse. Fuses are designed to break if their current limit is exceeded. Fuses are used to protect electronic devices and the circuits in automobiles.

Together, energy transducers, conductor paths, control devices, and output transducers make an electrical system. An electrical system can perform work. For example, to start an automobile we put a key in the ignition switch (control device) and turn it to the start position. The chemical energy in the battery (energy transducer) is converted to electrical energy. Electrons flow through the battery cables (conductor path) and carry the electrical energy to the starter motor. The starter motor (output transducer) converts the electrical energy provided by the battery into mechanical energy. The mechanical energy is used to turn the engine until it starts and we release the ignition switch.

Output transducers convert electrical energy to mechanical, thermal, radiant, and sound energy. Control devices are used to start, stop, and regulate the flow of current through a circuit. Control devices can be actuated with mechanical, thermal, radiant, or sound energy. In an electrical system, the energy transducer supplies energy to the circuit, the conductor path carries the energy, the control device control the flow of energy, and the output transducer uses the energy to perform work.

Learning Activities:

You use control devices and output transducers every day. When you enter a dark room, you flip a switch (control device) that turns on a light (output transducer). The switch completes the circuit and supplies electrical energy to the light fixture. The light fixture in turn converts the electrical energy to radiant energy and illuminates the room. During the lab activities, you will be making and testing a variety of electrical systems. Each electrical system will be using a different control device and output transducer.

LIGHT CIRCUIT

A light seems to go on automatically when we open a refrigerator door, oven door, car door, glove box door, or trunk lid. Even though it seems like magic, you know there are switches controlling these lights. If you have ever tried to find these switches, you know they are usually well hidden. During this lab activity, you will make and test a circuit that turns a light on and off when a door is opened.

Making a Light Circuit:

1. To make a simple light circuit, you will need:

    * 1 3 volt power supply
    * 1 pin switch or mercury switch
    * 1 lamp assembly
    * 4 jumper leads

2. Read the schematic drawings provided. Using the parts listed above, build the circuit as illustrated.

3. When your light circuit is complete, make sure it works. The light bulb should light when you lift the door. If the light does not work, check all your connections. If it still does not work, ask your teacher for assistance.

Testing your Light Circuit:

1. To test your light circuit, you will need a voltameter and a milliamp meter.

2. Measure and record the voltage across the power supply with a voltameter. With the light on, touch the positive test lead to the positive terminal of the energy transducer. Touch the negative test lead to the negative terminal of the energy transducer. Read the meter and record the voltage in the space below.

    __________ volts

3. Measure and record the voltage across the light bulb with a voltameter. With the circuit on, touch the positive test lead to the positive terminal on the lamp assembly. Touch the negative test lead to the negative terminal on the lamp assembly. Read the meter and record the voltage in the space below.

    __________ volts

4. The voltage measured at the energy transducer is _____ the voltage measured at the lamp assembly. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

5. Turn the light off. Install a milliamp meter in the circuit between the lamp assembly and the power supply. Connect the positive test lead to the jumper wire coming from the negative terminal on the lamp assembly. Connect the negative test lead to the jumper going to the negative terminal on the energy transducer.

6. When the meter is installed, turn the light back on. Read the meter and record the current in the space below.

   __________ milliamps

7. Turn the light off. Read the meter and record the current in the space below.

   __________ milliamps

8. Current flows through the circuit when the switch is _____ Circle the best answer.

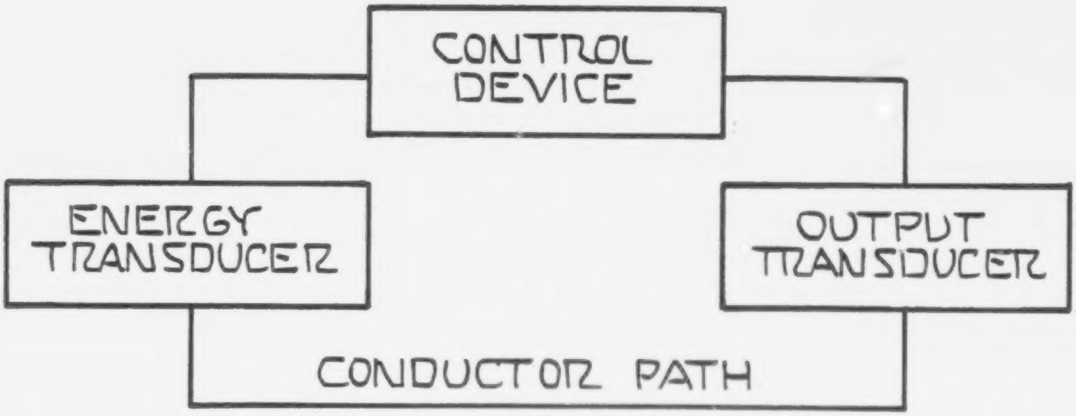
   A. open
   B. closed
   C. open or closed

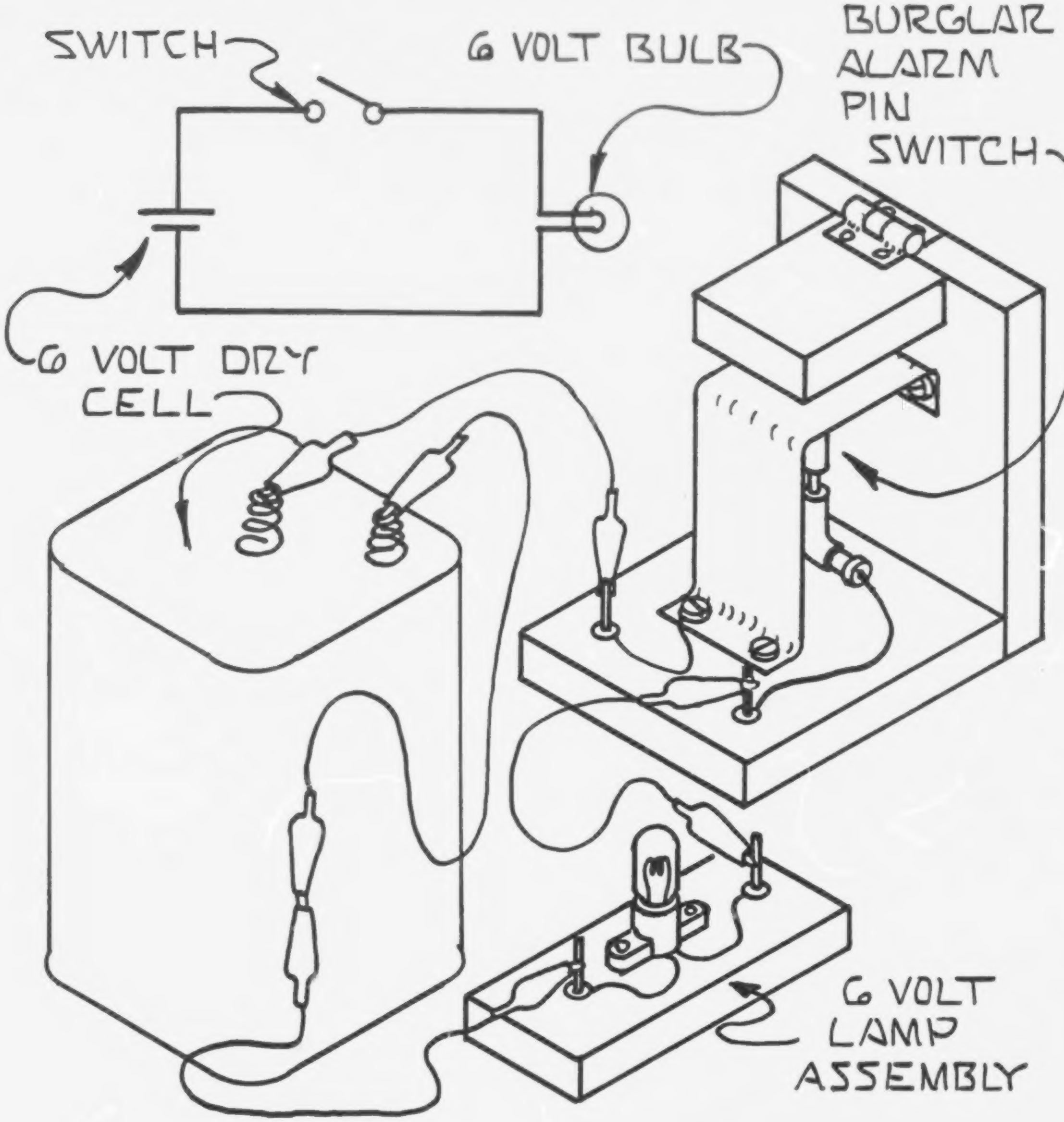
9. The control device in your circuit is _____ actuated. Circle the best answer.

   A. mechanically
   B. light
   C. heat
   D. magnetically

10. The output transducer in your circuit converts electrical energy to _____ energy. Circle the best answer.

   A. radiant (light)
   B. thermal (heat)
   C. mechanical (motion)
   D. sound


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


SWITCH
6 VOLT BULB
BURGLAR ALARM PIN SWITCH
6 VOLT DRY CELL
6 VOLT LAMP ASSEMBLY

TEMPERATURE CONTROLLED CIRCUIT

Many electrical systems are temperature controlled. For example, air conditioners, whole house fans, and attic fans are designed to turn on automatically if it becomes too hot in parts of your house. Most automobiles have a warning light that tells the driver if the engine is overheating. During this lab activity, you will make and test a temperature controlled circuit.

Making a Temperature Controlled Circuit:

1. To make a simple temperature controlled circuit, you will need:

   * 1 6 volt power supply
   * 1 thermostat
   * 1 lamp assembly
   * 4 jumper leads
   * 1 electric hair dryer

2. Read the schematic drawings provided. Using the parts listed above, build the circuit as illustrated.

3. When your light circuit is complete, make sure it works. Set the thermostat for about 75 degrees. Use the hair dryer, blow hot air at the thermostat. Hold the hair dryer at least 9 inches away from the thermostat. When the thermometer on the thermostat reads about 75 degrees, the light bulb should light. When the thermostat cools off, the light should turn off. If the light does not work, check all your connections. If it still does not work, ask your teacher for assistance.

Testing your Temperature Controlled Circuit:

1. To test your light circuit, you will need a volt meter and a milliamp meter.

2. Measure and record the voltage across the energy transducer with a volt meter. Touch the positive test lead to the postive terminal of the energy transducer. Touch the negative test lead to the negative terminal of the power supply. Read the meter and record the voltage in the space below.

   __________ volts

3. Measure and record the voltage across the light bulb with a volt meter. With the circuit on, touch the positive test lead to the positive terminal on the lamp assembly. Touch the negative test lead to the negative terminal on the lamp assembly. Read the meter and record the voltage in the space below.

_________ volts

4. The voltage measured at the energy transducer is _____ the voltage measured at the lamp assembly. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

5. Turn the circuit off by allowing the thermostat to cool or by removing one of the jumper leads on the energy transducer. Install a milliamp meter in the circuit between the lamp assembly and the energy transducer. Connect the postive test lead to the jumper wire coming from the negative terminal on the lamp assembly. Connect the negative test lead to the jumper going to the negative terminal on the energy transducer.

6. When the meter is installed, turn the circuit back on. Use the hair dryer if necessary. Read the meter and record the current in the space below.

_________ milliamps

7. Turn the circuit off by removing a jumper lead from the energy transducer. Read the meter and record the current in the space below.

_________ milliamps

8. Current flows through the circuit when the switch is _____. Circle the best answer.

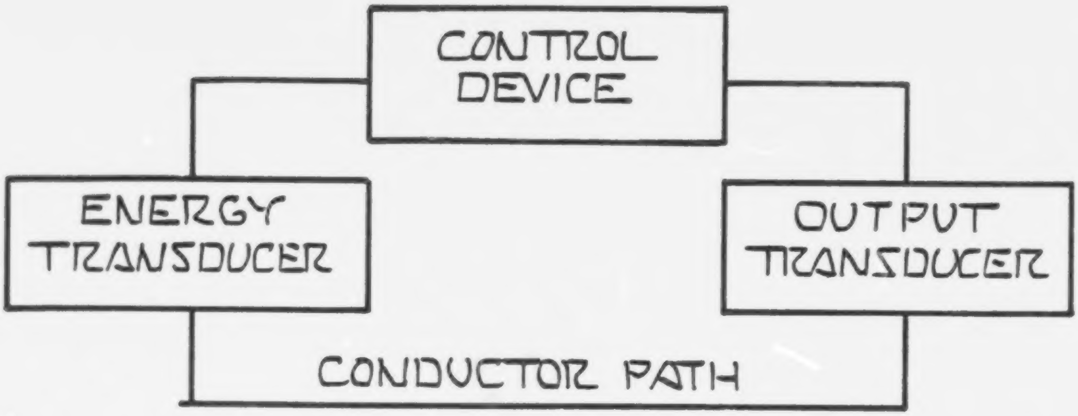
   A. open
   B. closed
   C. open or closed

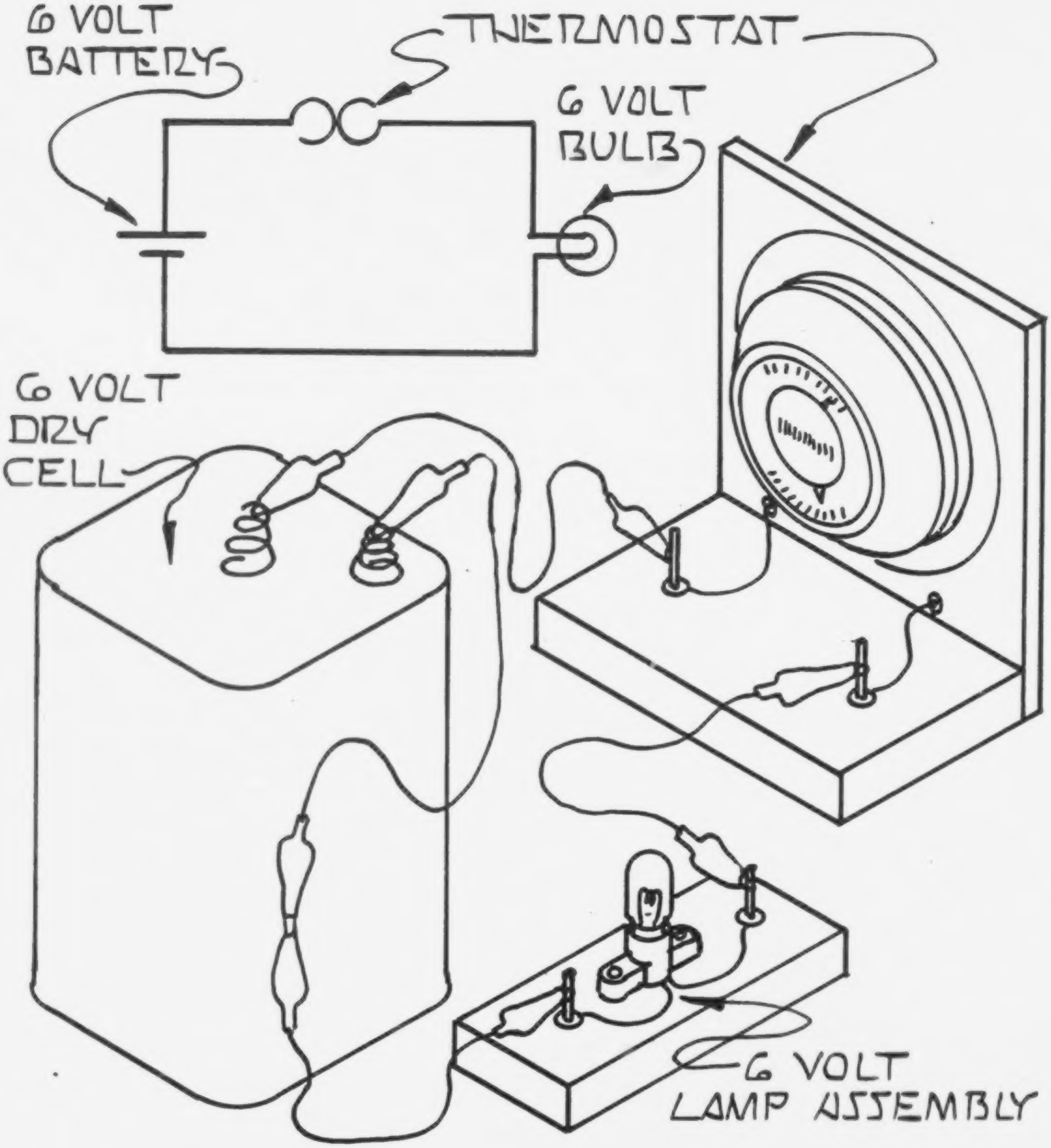
9. The control device in your circuit is _____ actuated. Circle the best answer.

   A. mechanically
   B. light
   C. heat
   D. magnetically

10. The output transducer in your circuit converts electrical energy to _____ energy. Circle the best answer.

A. radiant (light)
B. thermal (heat)
C. mechanical (motion)
D. sound


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


6 VOLT BATTERY
THERMOSTAT
6 VOLT BULB
6 VOLT DRY CELL
6 VOLT LAMP ASSEMBLY

LIGHT METER CIRCUIT

Electrical systems that can measure light can be very useful tools. Professional photographers use a hand held light meter to measure the light being reflected on a subject. They use the reading to adjust the exposure on their camera before taking pictures. Some cameras have built-in light meters that automatically adjust the camera to take the best picture possible. During this lab activity, you will make and test a simple light meter.

Making a Light Meter:

1. To make a simple light meter, you will need:

    * 1 3 volt power supply
    * 1 photocell
    * 1 milliamp meter
    * 3 jumper leads

2. Read the schematic drawings provided. Use the parts listed above to build the circuit as illustrated.

3. When your light meter is complete, make sure it works. Cover the photocell with your hand, the needle on the meter should move toward zero. Take your hand away from the photocell, the needle on the meter should move across the dial. If the meter movement does not move with changes in light, check all your connections. If it still does not work, ask your teacher for assistance.

Testing your Light Meter:

1. All you need to test your light meter, is a voltameter.

2. Measure and record the voltage across the energy transducer with a volt meter. With the circuit on, touch the positive test lead to the positive terminal of the energy transducer. Touch the negative test lead to the negative terminal of the energy transducer. Read the meter and record the voltage in the space below.

    __________ volts

3. Measure and record the voltage across the milliamp meter with a volt meter. With the circuit on, touch the positive test lead to the positive terminal on the milliamp meter. Touch the negative test lead to the negative terminal on the milliamp meter. Read the meter and record the voltage in the space below.

    __________ volts

4. The voltage measured at the power source is _____ the voltage measured at the meter movement. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

5. The voltage measured at the output should equal the voltage measured at the energy transducer. Another device in the circuit must be using electrical energy. Measure the voltage across the photocell. Touch the positive test lead to the positive terminal on the photocell. Touch the negative test lead to the negative terminal on the photocell. Read the meter and record the voltage in the space below.

   __________ volts

6. Add the voltage measured across the meter movement to the voltage measured across the photocell.

   _____ volts + _____ volts = _____ volts

7. The voltage measured across the energy transducer is _____ to the sum of the voltages measured across the meter movement and the photocell. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

8. Put your hand over the top of the photocell. Read the milliamp meter and record the current in the space below.

   __________ milliamps

9. Slowly remove your hand from the photocell and watch the meter. When your hand is completely away, read the milliamp meter and record the current in the space below.

   __________ milliamps

10. Current flowing through the circuit _____ when the photocell is exposed to light. Circle the best answer.

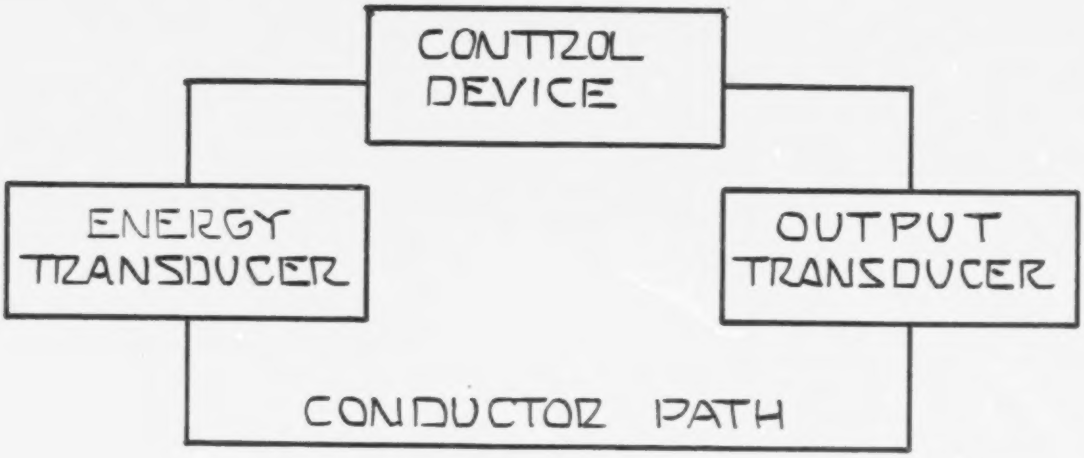
   A. increases
   B. decreases
   C. stays the same

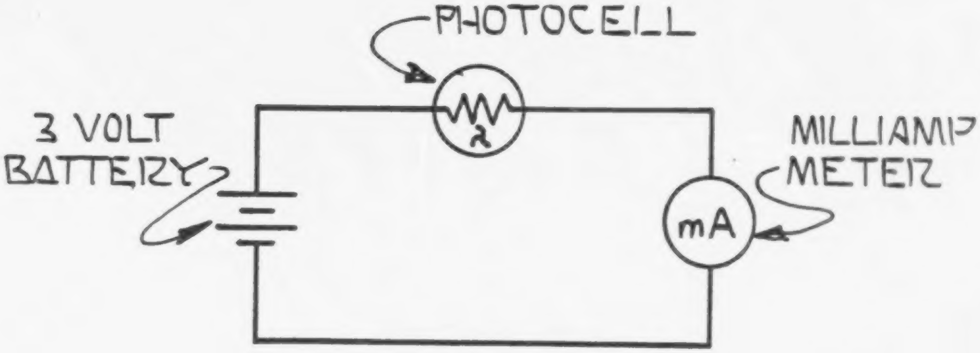
11. The control device in your circuit is _____ actuated. Circle the best answer.

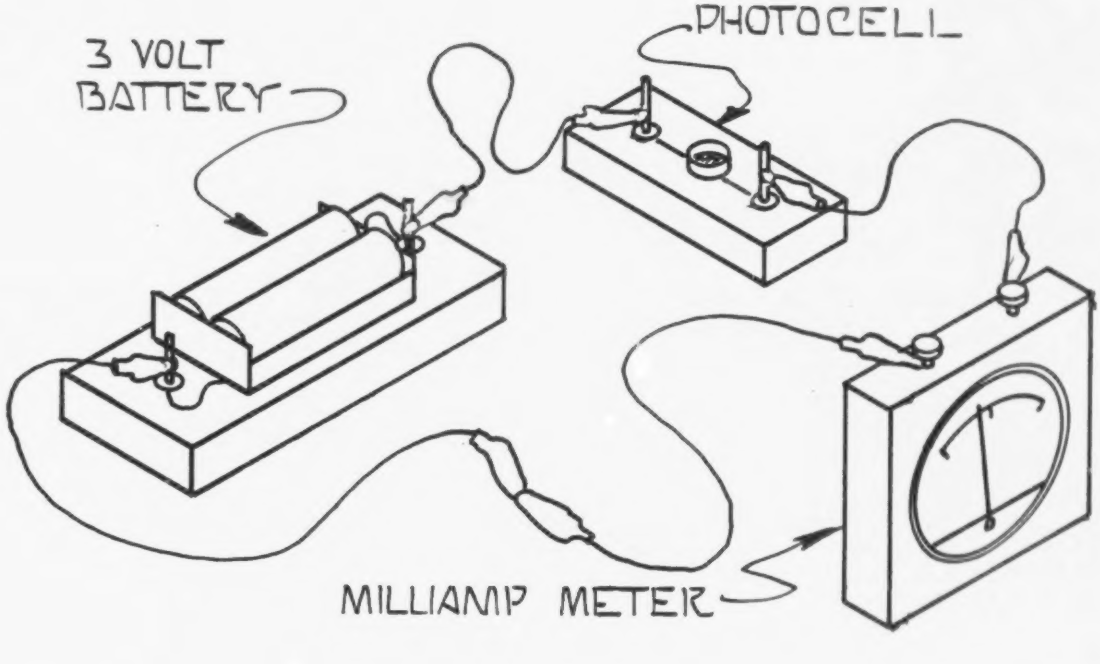
    A. mechanically
    B. light
    C. heat
    D. magnetically

12. The output transducer (milliamp meter) in your circuit converts electrical energy to _____ energy. Circle the best answer.

    A. radiant (light)
    B. thermal (heat)
    C. mechanical (motion)
    D. sound


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


PHOTOCELL
3 VOLT BATTERY
MILLIAMP METER
mA


PHOTOCELL
3 VOLT BATTERY
MILLIAMP METER

VARIABLE SPEED ELECTRIC MOTOR CIRCUIT

Our world is full of motor driven devices, portable power tools, golf carts, tape players, electric fans, and food processors to name just a few. Many of these motor driven devices have speed controls. During this lab activity, you will maker and test a circuit that features a variable speed electric motor.

Making a Variable Speed Electric Motor Circuit:

1. To make a variable speed electric motor circuit, you will need:

   - 1 3 volt power supply
   - 1 10k-ohm potentiometer with on/off switch
   - 1 3 volt hobby motor
   - 4 jumper leads

2. Read the schematic drawings provided. Using the parts list above, build the circuit as illustrated.

3. When your motor circuit is complete, make sure it works. The motor should begin to turn when you turn the knob on the variable resistor. The speed of the motor should increase as you turn the knob. If your motor does not turn, check all your connections. If it still does not work, ask your teacher for assistance.

Testing your Variable Speed Electric Motor Circuit:

1. To test your motor circuit, you will need a voltameter and a milliamp meter.

2. Measure and record the voltage across the energy transducer with a volt meter. With the circuit on, touch the positive test lead to the positive terminal of the energy transducer. Touch the negative test lead to the negative terminal of the energy transducer. Read the meter and record the voltage in the space below.

   __________ volts

3. Set the variable resistor so your motor is turned as slowly as possible. Measure the voltage across the motor with a volt meter. With the motor turning, touch the positive test lead to the positive terminal on the motor. Touch the negative test lead to the negative terminal on the motor. Read the meter and record the voltage in the space below.

   __________ volts

4. The voltage measured at the energy transducer is _____ the voltage measured at the motor. Circle the best answer

   A. greater than
   B. less than
   C. equal to

5. The voltage across the energy transducer should be the same as the voltage measured across the load. There must be another device in the circuit using electrical energy. Measure the voltage across the variable resistor. Touch the positive test lead to the positive terminal on the variable resistor. Touch the negative test lead to the negative terminal on the variable resistor. Read the meter and record the voltage in the space below.

   _________ volts

6. Add the voltage measured across the variable resistor to the voltage measured across the motor.

   _______ volts + ______ volts = ______ volts

7. The voltage measured across the energy transducer is _____ the sum of the voltages measured across the resistor and the motor. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

8. To check the statement above, adjust the resistor so the motor is turning as fast as possible. Measure the voltage across the resistor. Record its voltage in the space provided. Measure the voltage across the motor. Record the voltage in the space provided. Add the two voltages together

   __________ + __________ = __________

9. The voltage measured at the resistor plus the voltage measured at the motor is _____ the voltage measured at the energy transducer. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

10. Turn the circuit off. Install a milliamp meter in the circuit between the motor and the energy transducer. Connect the positive test lead to the jumper wire coming from the negative terminal of the motor. Connect the negative test lead to the jumper wire going to the negative terminal on the energy transducer.

11. When the meter is installed, turn the motor on. Slowly decrease the resistance in the circuit by turning the knob while watching the milliamp meter.

12. The current in the circuit _____ when the resistance is decreased. Circle the best answer.

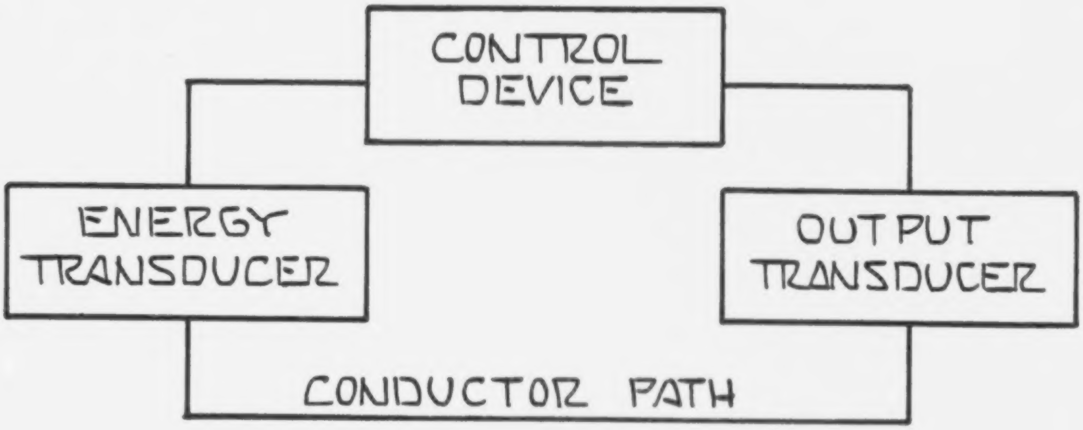
    A. increases
    B. decreases
    C. stays the same

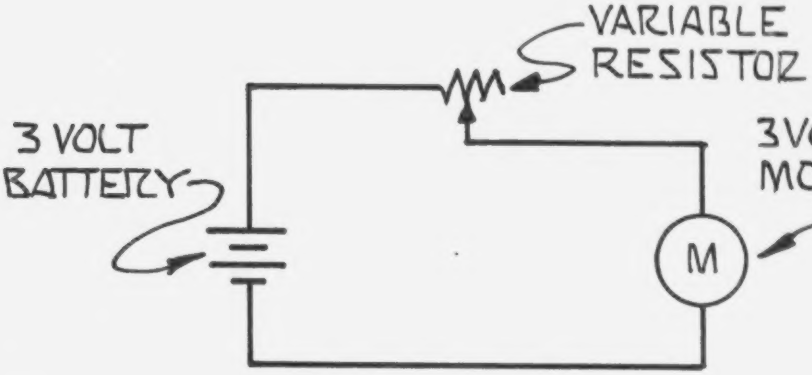
13. The control device in your circuit is _____ actuated. Circle the best answer.

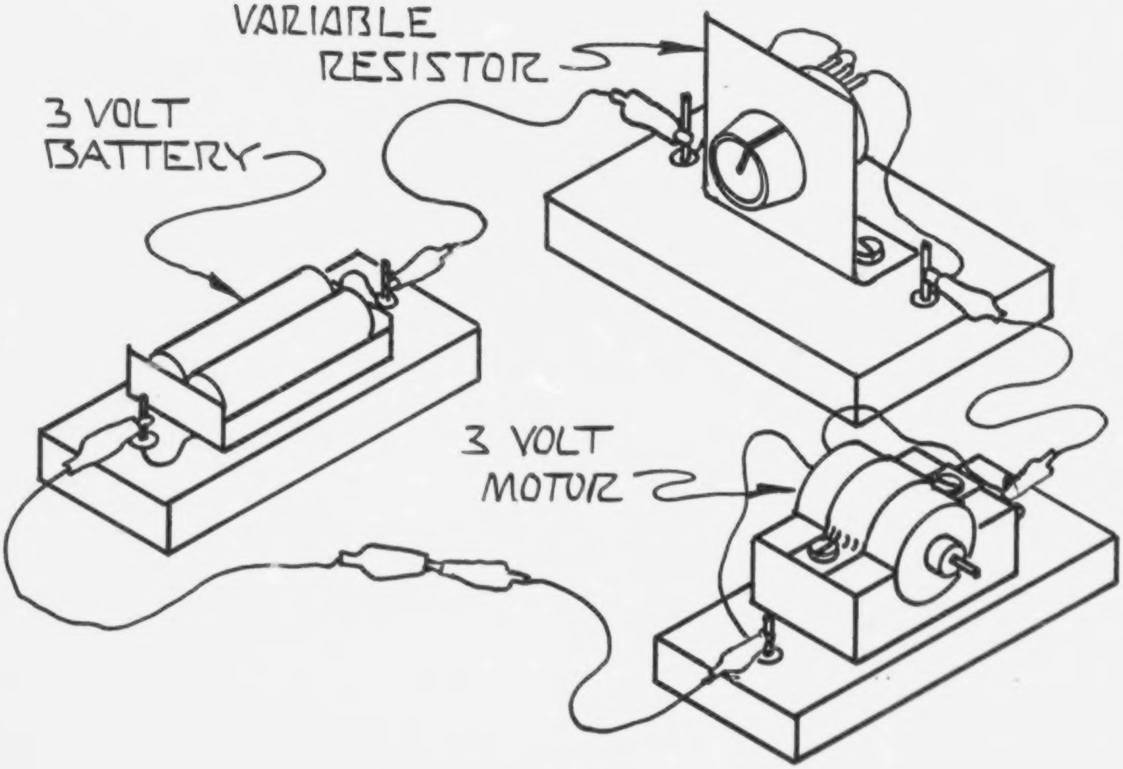
    A. mechanically
    B. light
    C. heat
    D. magnetically

14. The output transducer in your circuit converts electrical energy to _____ energy. Circle the best answer.

    A. radiant (light)
    B. thermal (heat)
    C. mechanical (motion)
    D. sound


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


VARIABLE RESISTOR
3 VOLT BATTERY
3 VOLT MOTOR
M


VARIABLE RESISTOR
3 VOLT BATTERY
3 VOLT MOTOR

ALARM CIRCUIT

Our world is full of alarms that tell us a process is complete or warn us when something is wrong. For example, microwave ovens often beep when the cooking cycle is finished. In some automobiles, a buzzer will sound if you leave your keys in the ignition, do not have your doors completely closed, leave the head lights on, or do not buckle your seat belt. Sometimes, we need to take some form of action to turn alarms off. During this lab activity, you will make and test an alarm circuit.

Making a Simple Alarm Circuit:

1. To make a simple alarm circuit, you will need:

    * 1 6 volt power supply
    * 1 magnetic switch that is normally open
    * 1 piezo electric buzzer
    * 4 jumper leads

2. Read the schematic drawings provided. Using the parts list above, build the circuit as illustrated.

3. When your alarm circuit is complete, make sure it works. When the magnet is removed from its base, the buzzer should sound. When the magnet is returned to its base, the buzzer should stop. If the buzzer does not sound, check all your connections. If it still does not work, ask your teacher for assistance.

Testing the Light Circuit

1. To test your alarm circuit, you will need a volt meter and a milliamp meter.

2. Measure and record the voltage across the energy transducer with a volt meter. With the circuit on, touch the positive test lead to the positive terminal of the energy transducer. Touch the negative test lead to the negative terminal of the energy transducer. Read the meter and record the voltage in the space below.

    __________ volts

3. Measure and record the voltage across the buzzer with a volt meter. With the circuit on, touch the positive test lead to the positive terminal on the buzzer. Touch the negative test lead to the negative terminal on the buzzer. Read the meter and record the voltage in the space below.

    __________ volts

4. The voltage measured at the energy transducer is _____ the voltage measured at the buzzer. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

5. Turn the circuit off. Install a milliamp meter in the circuit between the buzzer and the energy transducer. Connect the positive test lead to the jumper wire coming from the negative terminal on the buzzer. Connect the negative test lead to the jumper going to the negative terminal on the energy transducer.

6. When the meter is installed, trip the alarm. Read the meter and record the current in the space below.

   __________ milliamps

7. Turn the circuit off. Read the meter and record the current in the space below.

   __________ milliamps

8. Current flows through the circuit when the switch is_____. Circle the best answer.

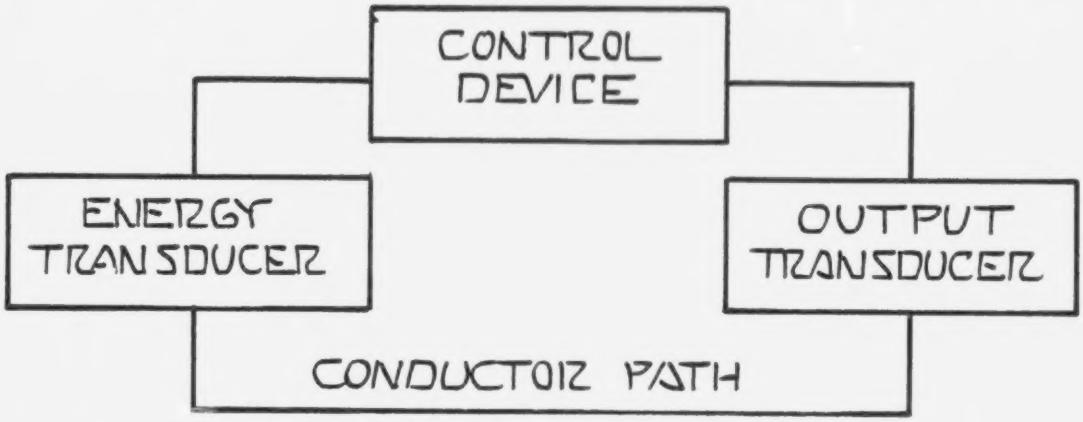
   A. open
   B. closed
   C. open or closed

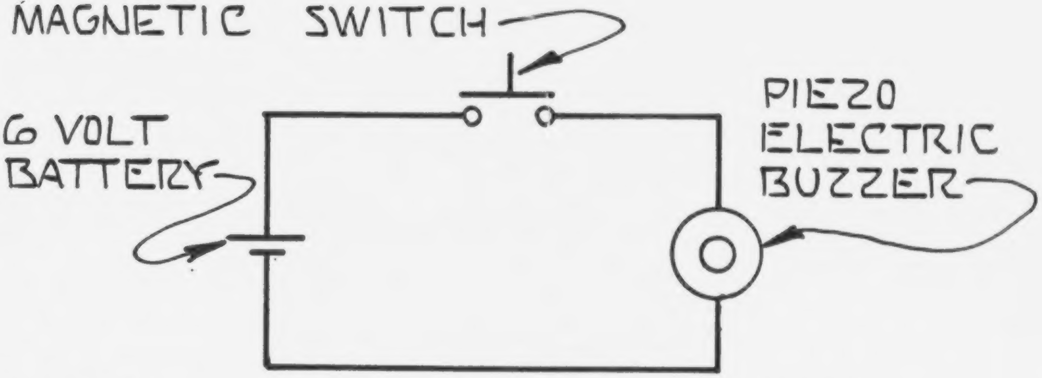
9. The control device in your circuit is _____ actuated. Circle the best answer.

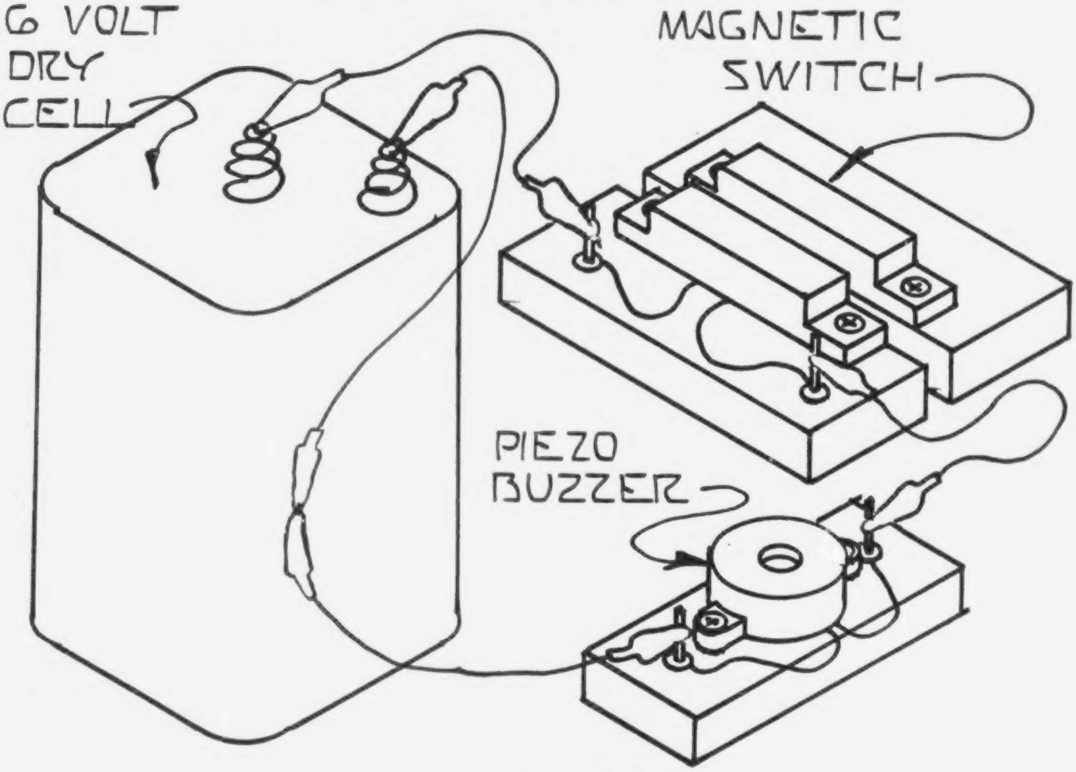
   A. mechanically
   B. light
   C. heat
   D. mechanically

10. The output transducer in your circuit converts electrical energy to _____ energy. Circle the best answer.

   A. radiant (light)
   B. thermal (heat)
   C. mechanical (motion)
   D. sound


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


MAGNETIC SWITCH
6 VOLT BATTERY
PIEZO ELECTRIC BUZZER


6 VOLT DRY CELL
MAGNETIC SWITCH
PIEZO BUZZER

Unit: Exploring Electricity/Electronics — Lesson 4: Series and Parallel Circuits

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for a series circuit. -identify the voltage and current characteristics of a series circuit. -identify a definition for a parallel circuit. -identify the voltage and current characteristics of a parallel circuit. -identify a definition for a complex circuit. -draw a block diagram for a series circuit. -draw a block diagram for a parallel circuit.	A. Series and parallel circuits 1. Three basic types of circuits a. series circuit b. parallel circuit c. complex circuit 2. Series circuits a. one conductor path b. current is the same throughout the circuit c. voltage divides across the output transducers d. voltage rise = the sum of the voltage drops 3. Parallel circuits a. more than one conductor path b. voltage is constant throughout the circuit c. current divides among the circuit branches d. total current = the sum of the branch of currents 4. Complex circuits a. integrates both series and parallel conductor paths b. sometimes called series-parallel circuit	A. Teacher Guided Discussion	TA #4-1
		1. Ask students if they have ever looked at the circuit board inside an electronic device. Discuss how complicated electrical systems can be.	
		2. Using OT #4-1, introduce students to the three basic types of electrical circuits.	OT #4-1
		3. Using OT #4-2, discuss the definition for a series circuit. Describe the voltage and current characteristics of a series circuit.	OT #4-2
		4. Using OT #4-3, discuss the definition for a parallel circuit. Describe the voltage and current characteristics of a parallel circuit.	OT #4-3
		5. Using OT #4-4, discuss the definition for a complex circuit.	OT #4-4

B. Following a demonstration, in a lab activity, students will be able to:
- -use schematic drawings and electrical components to build working series and parallel circuits.
- -measure voltage and current in series and parallel circuits
- -complete statements describing voltage and current characteristics in series and parallel circuits

B. Making and testing series and parallel circuits.
1. Making circuits
   a. energy transducers in series
   b. energy transducers in parallel
   c. control devices in series
   d. control devices in parallel
   e. output transducers in series
   f. output transducers in parallel
2. Testing circuits
   a. measuring voltage in a series circuit
   b. measuring voltage in a parallel circuit
   c. measuring current in a series circuit
   d. measuring current in a parallel circuit
   e. completing lab sheets

B. Learning Activity
1. Explain how to use schematic drawings to build working series and parallel circuits.
2. Demonstrate how to measure voltage and current in a series circuit.
3. Demonstrate how to measure voltage and current in a parallel circuit.
4. Provide students with HO #4-1 through HO #4-3. Divide the class in groups of three to four students.
5. Assign each group a work station and have them complete the lab activity.
6. When students have finished the lab activity, rotate them to the next work station.
7. Circulate around the room and provide individual instruction as needed.
8. When students have finished all three lab activities, ask students questions about the characteristics of each circuit.
9. Collect and evaluate the lab sheets for all three lab activities.

HO #4-1
HO #4-2
HO #4-3

SERIES AND PARALLEL CIRCUITS

Preparation Hints:

1. Review the materials provided, duplicate HO #4-1 through HO #4-3, and prepare the transparencies needed to present this lesson.

2. During the lab activity, your students will be making and testing a variety of circuits. Prior to implementing this lesson, you will need to collect and organize the materials listed in the handouts. You will be using many of the same energy transducers, control devices, and output transducers used in previous lab activities. However, since components will be connected in series and in parallel, you may need additional batteries, switches, and lamp assemblies.

3. Prior to implementing this lesson, consider mounting new electronic components on fixtures similar to those illustrated in the handouts. Mounting the components will make them easier to handle and will extend their life considerably.

4. Prior to implementing this lesson, consider performing each of the lab activities. Making and testing each circuit will help you test your materials, anticipate problems and develop strategies for assuring student success.

Content Presentation Hints:

1. Consider constructing several mock-ups illustrating series and parallel circuits. Use batteries to illustrate energy transducers in series and parallel. Use electrical boxes, switches, and light fixtures to illustrate output transducers and control devices in series and parallel.

2. Consider showing a film or videotape on series and parallel circuits.

Learning Activity Hints:

1. If time is limited, divide your class into groups of three to four students and assign each group a circuit to build and test. By dividing each lab activity in half, one series circuit and one parallel circuit, you could have as many as six circuits being built at one time. When students have finished building and testing

their circuits, have each group explain and demonstrate how their circuit works to the rest of the class. During their presentations, students could describe the voltage and current characteristics of each circuit.

2. If time permits, allow the students to modify their circuits using different control devices and output transducers. For example, students could build a circuit featuring two pin switches in parallel connected to a piezo electric buzzer. Students could measure changes in current while adding additional output transducers to a series and/or parallel circuit.

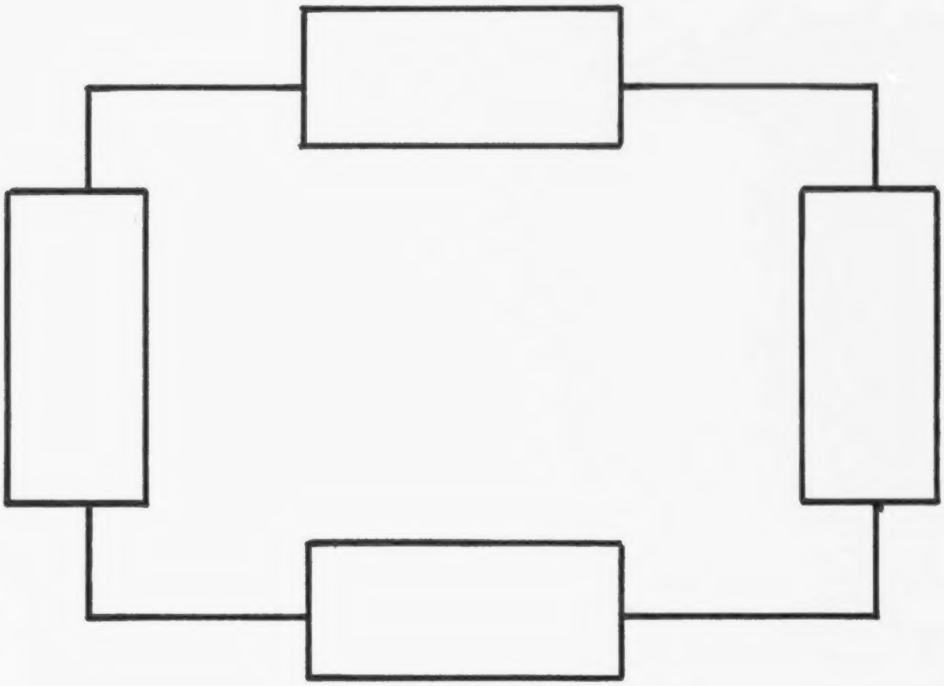
3. When students have finished the lab activities, consider displaying their electrical circuits in a location where the rest of the school community can see the results of their circuit analysis activities.

Three basic types of circuits:

- * series
- * parallel
- * complex

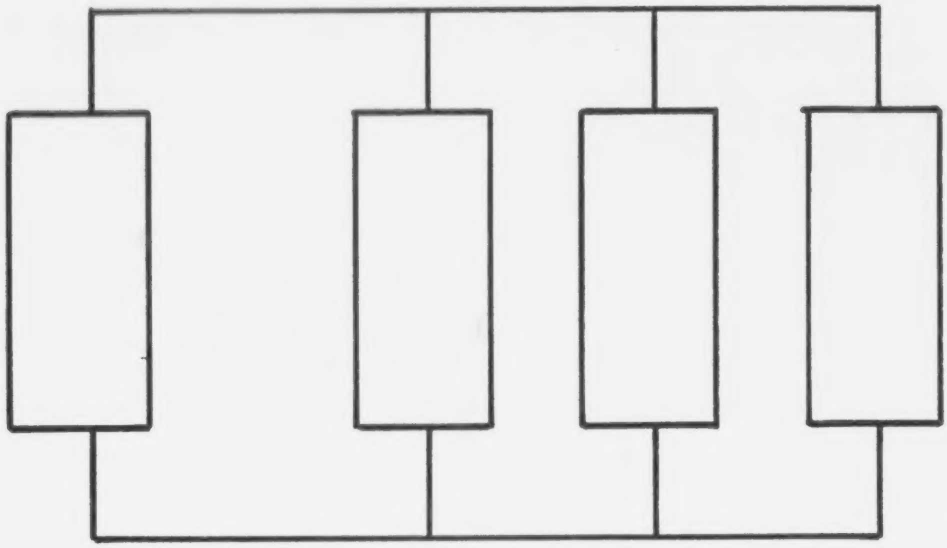
Series circuits:

- * one conductor path
- * current is the same throughout the circuit
- * voltage divides across the output transducers
- * voltage rise = the sum of the voltage drop



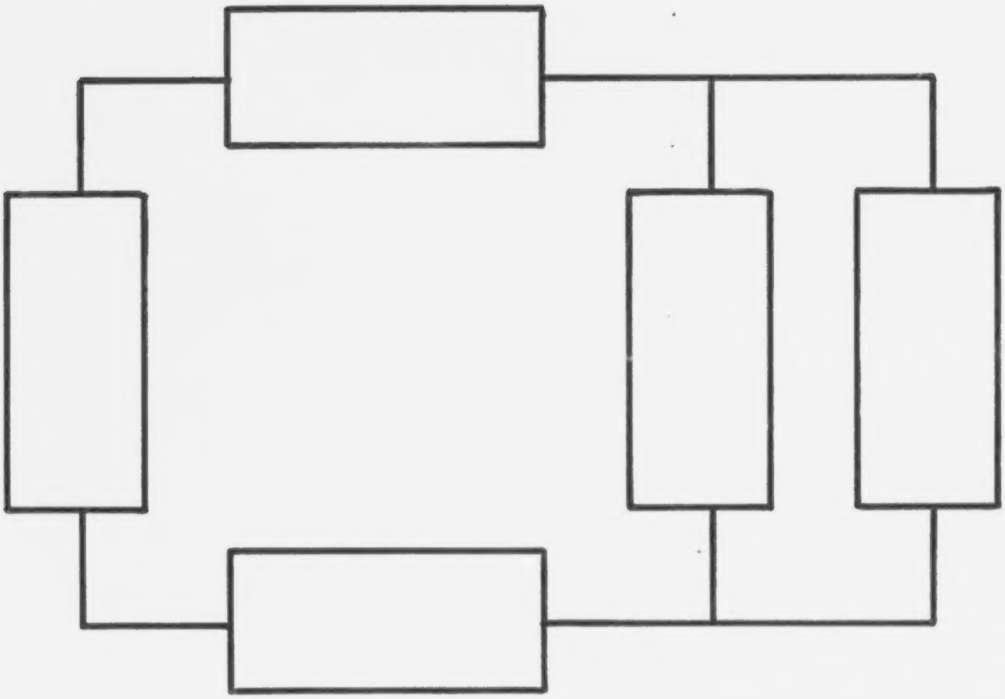
Parallel Circuits:

- * more than one conductor path
- * voltage is constant throughout the circuit
- * current divides among the circuit branches
- * total current = the sum of the branch of currents



Complex circuits:

- * integrates both series and parallel conductor paths
- * sometimes called series-parallel circuit



SERIES AND PARALLEL CIRCUITS

Discussion:

If you have ever looked inside a portable radio, microcomputer, or electronic game, you know they have very complicated circuits. They look complicated because electronic devices often have more than one circuit. In addition, they often use more than one type of circuit to perform a given task.

The way energy transducers, control devices, and output transducers are arranged in a circuit depends on the task that needs to be performed. There are three basic types of circuit arrangements. They are as follows:

- series circuits
- parallel circuits
- complex circuits

A series circuit has only one conductor path. The electrons traveling through a series circuit must go through every component. Current in a series circuit is the same, no matter where it is measured in the circuit.

When energy transducers are connected in series, their potential differences combine. Their total voltage being applied to the circuit equals the sum of their individual voltages. The voltage applied to the circuit by the energy transducer is called the voltage rise.

When output tranducers are connected in series, they share the voltage in the circuit. The voltage measured across an output transducer is called a voltage drop. The output transducer converting the most electrical energy will have the highest voltage drop. The output transducer converting the least amount of electrical energy will have the lowest voltage drop. The sum of all voltage drops in a series circuit will equal the voltage rise.

If control devices are connected in series, they work together to regulate current in the circuit. If one switch is off, the circuit will be open, and current will not flow. In order for current to flow, the circuit needs to be closed, and all the control devices must be on.

A parallel circuit has more than one conductor path. The electrons in a parallel circuit can travel through one of several branches. Current can flow through one component without flowing through another component first. The voltage measured across all the energy transducers and output transducers in a parallel circuit are the same.

When energy transducers are connected in parallel, their total voltage is the same as their individual voltages. However, they all contribute energy to the work being performed in the circuit. Each energy transducer contributes electrons to the flow of current in the circuit. The total current in the circuit equals the sum of the individual branch currents.

Like energy transducers, output transducers connected in parallel have to share the current in the circuit. The output transducer converting the most electrical energy will have the highest branch current. The output transducer converting the least amount of electrical energy will have the lowest branch current. The sum of all individual branch currents will equal the total current flow through the circuit.

Control devices connnected in parallel work individually to regulate current in the circuit. Actuating any of the control devices will complete the circuit and current will flow.

Complex circuits use both series and parallel conductor paths to connect energy transducers, control devices, and output transducers into a working circuit. For example, you need to turn on two 12 volt light bulbs with two 6 volt batteries and a switch. The light bulbs will need to be connected in parallel so each will receive 12 volts. The 6 volt batteries need to be connected in series so their total voltage equals 12 volts. The switch needs to be installed in series between the batteries and the light bulbs. Together, the batteries in series, the light bulbs in parallel, and the switch make a complex circuit.

There are three basic types of circuits, series circuits, parallel circuits, and complex circuits. Series circuits have one conductor path, parallel circuits have more than a conductor path, and complex circuits contain a combination of series and parallel conductor paths. Current is the same throughout a series circuit. The sum of voltage drops in a series circuit equals the voltage rise. Voltage is the same through a parallel circuit. The sum of the individual branch currents in a parallel circuit equals the total current in the circuit.

Learning Activities:

Most electrical systems use complex circuits. The first step in understanding complex circuits is to understand the simple circuits. After all, a complex circuit is nothing more than a collection of simple series and parallel conductor paths. During the lab activities, you will be making and testing a variety of series and parallel circuits.

ENERGY TRANSDUCERS IN SERIES AND PARALLEL CIRCUITS

Batteries often have to be installed in series for many portable stereos, tape recorders, and electronic toys to work. In other applications, like jump starting an automobile, batteries need to be connected in parallel. Each circuit has different voltage and current characteristics. During the following lab activity, you will make and test two circuits. One circuit will have two energy transducers connected in series. The second circuit will have two energy transducers connected in parallel.

Making and Testing a Series Circuit:

1. To perform the following lab activity, you will need:

   * 2 3 volt energy transducers
   * 1 piezo electric buzzer
   * 1 switch
   * 5 jumper leads
   * 1 volt meter
   * 1 milliamp meter

2. Using the parts listed above, make the circuit illustrated in Figure 4-1.

3. When your circuit is complete, make sure it works. The piezo should sound when the switch is closed. If your buzzer does not sound, check all your connections. If it still does not work, ask your teacher for assistance.

4. Measure the voltage across energy transducer number one with a volt meter. Touch the positive test lead to the positive terminal on the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Read the meter and record the voltage in the space below.

   _________ volts

5. Measure the voltage across energy transducer number two with a volt meter. Touch the positive test lead to the positive terminal on the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Read the meter and record the voltage in the space below.

   __________ volts

6. Add the voltages measured across the two energy transducers together.

_____ volts + _____ volts = _____ voltage rise

7. Measure the voltage across both energy transducers with a volt meter. Touch the positive test lead to the positive terminal on energy transducer number two. Touch the negative test lead to the negative terminal on energy transducer number one. Make sure both transducers are between the two test leads. Read the meter and record the voltage in the space below.

__________ volts

8. The voltage rise figured in step number 6 is _____ the voltage rise measured in step 7. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

9. Measure the current between the energy transducers and the output transducer with a milliamp meter. Connect the positive test lead to the jumper wire coming from the negative terminal on the output transducer. Connect the negative test lead to the jumper wire going to the negative terminal on energy transducer number one. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

10. Measure the current between the two energy transducers with a milliamp meter. Connect the positive test lead to the positive terminal on energy transducer number one. Connect the negative test lead to the negative terminal on energy transducer number two. Make sure the milliamp meter is between the two energy transducers. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

11. Current is the same no matter where it is measured in a series circuit. Circle the best answer.

   A. true
   B. false

Making and Testing a Parallel Circuit:

1. Take your series circuit apart and make the circuit illustrated in Figure 4-2.

2. When your circuit is complete, make sure it works. The piezo should sound when the switch is closed. If your buzzer does not sound, check all your connections. If it still does not work, ask your teacher for assistance.

3. Measure the voltage across the first energy transducer in the circuit with a volt meter. Touch the positive test lead to the positive terminal in the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Read the meter and record the voltage in the space below.

   __________ volts

4. Measure the voltage across the second energy transducer in the circuit with a volt meter. Touch the positive test lead to the positive terminal on the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Read the meter and record the voltage in the space below.

   __________ volts

5. The voltage measured across one energy transducer is _____ to the voltage measured across the second energy transducer. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

6. Measure the current flowing through energy transducer one. Connect the positive test lead to the negative terminal on energy transducer number one. Connect the negative test lead to the jumper wire. Turn the switch on, read the meter, and record the current in the space below.

   __________ milliamps

7. Measure the current flowing through energy transducer two. Connect the positive test lead to the negative terminal on energy transducer number one. Connect the negative test lead to the jumper wire. Turn the switch on, read the meter, and record the current in the space below.

   __________ milliamps

8. Add the two energy transducer branch currents together.

_____ milliamps + _____ milliamps = _____ milliamps

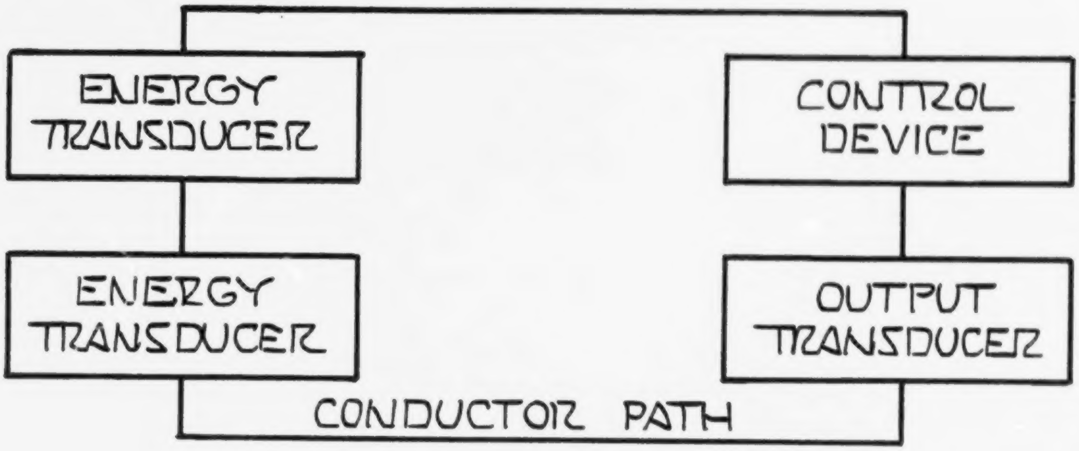
9. Measure the current between the energy transducers and the output transducer with a milliamp meter. Connect the positive test lead to the jumper wire coming from the negative terminal on the output transducer. Connect the negative test lead to the jumper wire going to the negative terminal on the second energy transducer. Turn the switch on, read the meter, and record the current in the space below.

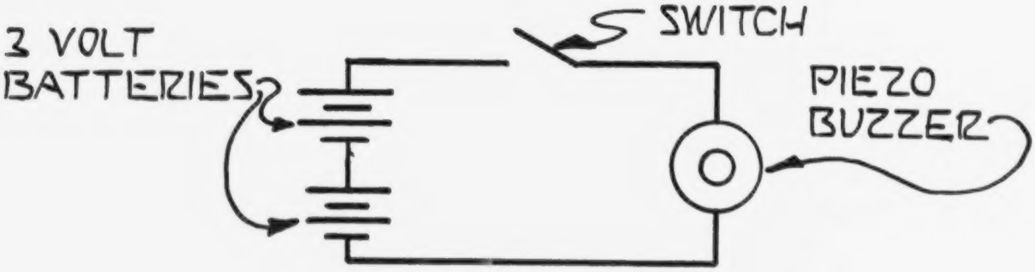
__________ milliamps

10. The sum of the branch currents (figured in step #9) is _____ the current measured in step number 10. Circle the best answer.

A. greater than
B. less than
C. equal to

FIGURE 4-1


ENERGY TRANSDUCER
CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH


SWITCH
3 VOLT BATTERIES
PIEZO BUZZER

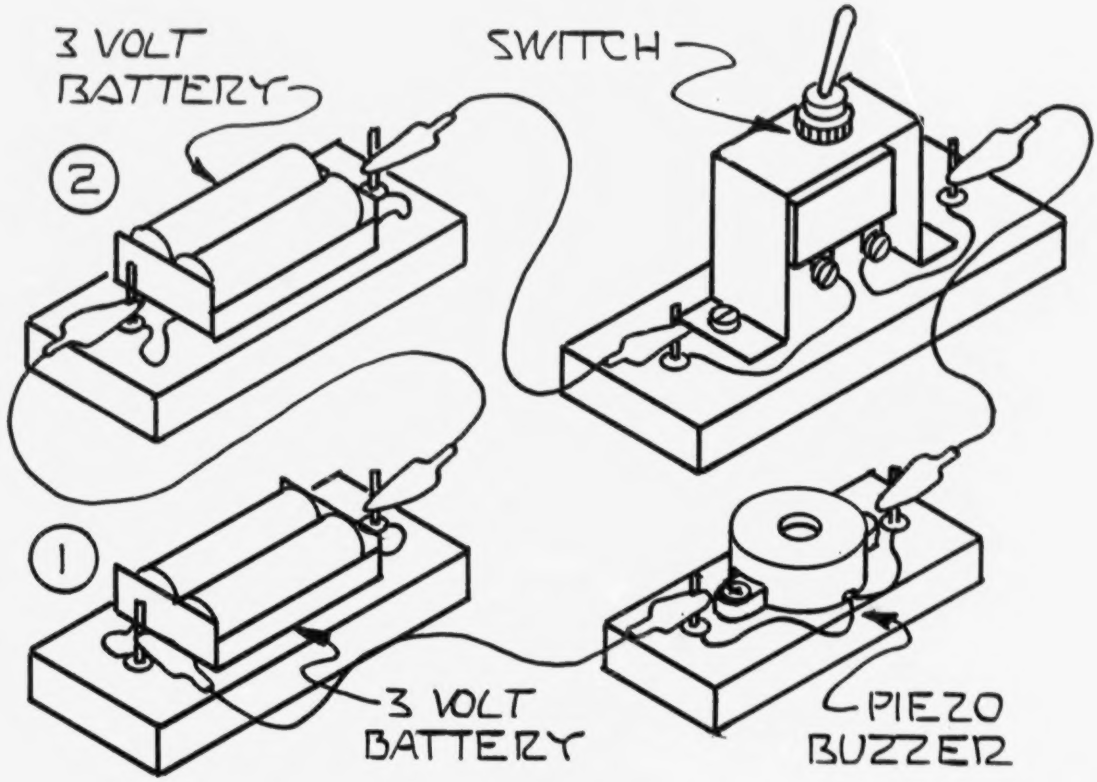
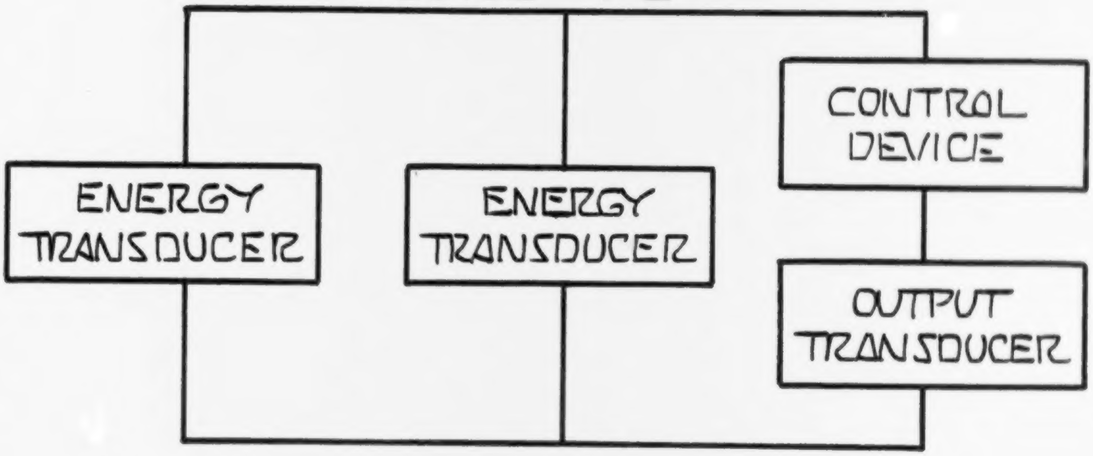
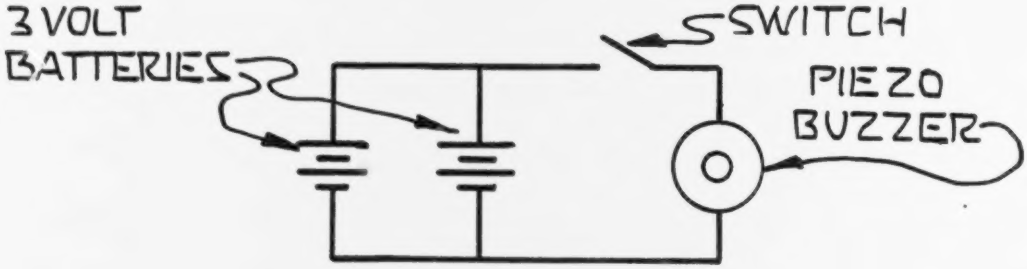
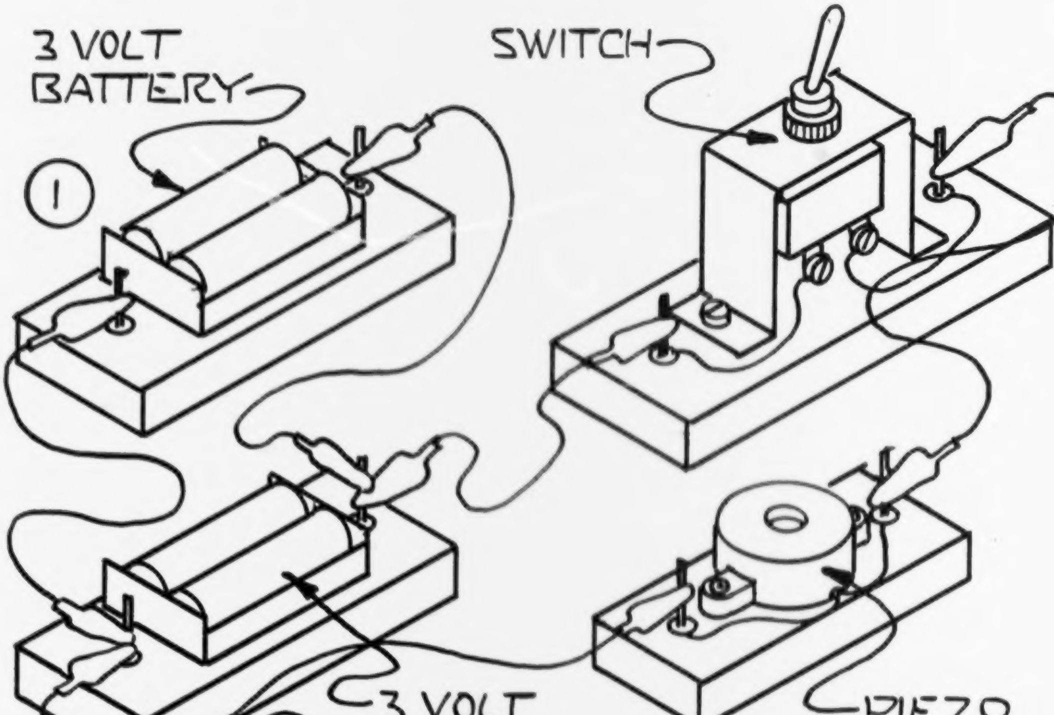

3 VOLT BATTERY
SWITCH
②
①
3 VOLT BATTERY
PIEZO BUZZER

FIGURE 4-2


ENERGY TRANSDUCER
ENERGY TRANSDUCER
CONTROL DEVICE
OUTPUT TRANSDUCER


3 VOLT BATTERIES
SWITCH
PIEZO BUZZER


3 VOLT BATTERY
①
SWITCH
②
3 VOLT BATTERY
PIEZO BUZZER

CONTROL DEVICES IN SERIES AND PARALLEL CIRCUITS

Some circuits require two control devices. For example, some of the lights in our home can be turned on and off from two or more switches. Some industrial machines require the operator to hold two switches down before the machine will work. Holding down two switches insures that the operator's hands are in a safe location while the machine performs a dangerous process. During the following lab activity, you will make and test two circuits. One circuit will have two control devices connected in series. The second circuit will have two control devices connected in parallel.

Making and Testing a Series Circuit:

1. To perform the following lab activity, you will need:

   * 1 3 volt energy transducer
   * 1 3 volt hobby motor
   * 2 switches
   * 6 jumper leads
   * 1 milliamp meter

2. Using the parts listed above, make the circuit illustrated in Figure 4-3. Make sure both control devices are in their off position before you connect the energy transducer. Install a milliamp meter between the output transducer and the energy transducer. Connect the positive test lead to the negative terminal on the output transducer. Connect the negative test lead to the negative terminal on the energy transducer.

3. When your circuit is complete, lets test it. Turn control device number one to the on position. Read the milliamp meter and record the current in the space below.

   __________ milliamps

   Is the motor in the circuit running? Circle the best answer.

   A. yes
   B. no

4. Turn control device number one off. Turn control device number two to its on position. Read the milliamp meter and record the current in the space below.

   __________ milliamps

Is the motor in your circuit running? Circle the best answer.

A. yes
B. no

5. Try turning both control devices to their on position. Read the milliamp meter and record the current in the space below.

__________ milliamps

Is the motor in your circuit running? Circle the best answer.

A. yes
B. no

6. Control devices connected in series control current _____.

A. independently
B. together

7. If one or more control devices in a series circuit are in the off position, the conductor path is _____.

A. open
B. closed

8. If two control devices are connected in series, _____ must be in the on position for current to flow in the circuit.

A. one
B. both

Making and Testing a Parallel Circuit:

1. Take your series circuit apart and make the circuit illustrated in Figure 4-4. Make sure both control devices are in their off position before you connect the energy transducer.

2. When your circuit is complete, let's test it. Turn control device number one to the on position. Read the milliamp meter and record the current in the space below.

__________ milliamps

Is the motor in your circuit running? Circle the best answer.

A. yes
B. no

3. Turn control device number one off. Turn control device number two to its on position. Read the milliamp meter and record the current in the space below.

__________ milliamps

Is the motor in your circuit running? Circle the best answer.

A. yes
B. no

4. Try turning both control devices to their on position. Read the milliamp meter and record the current in the space below.

__________ milliamps

Is the motor in your circuit running? Circle the best answer.

A. yes
B. no

5. Control devices connect in parallel control current _____.

A. independently
B. together

6. If one or more control devices in a parallel circuit are in the on position, the conductor path is _____.

A. open
B. closed

7. If two control devices are connected in parallel, _____ must be in the on position for current to flow in the circuit.

A. one
B. both

FIGURE 4-3

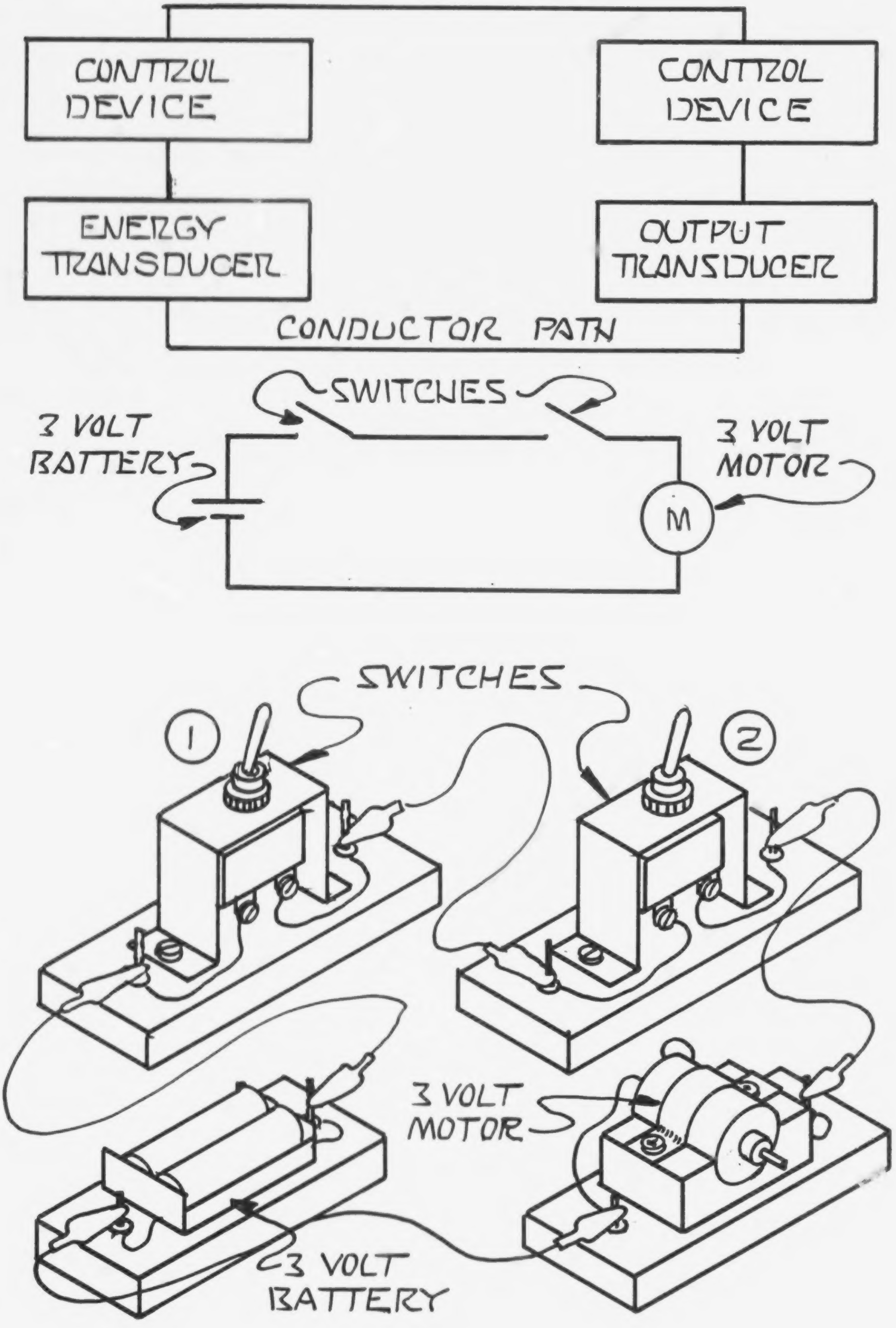
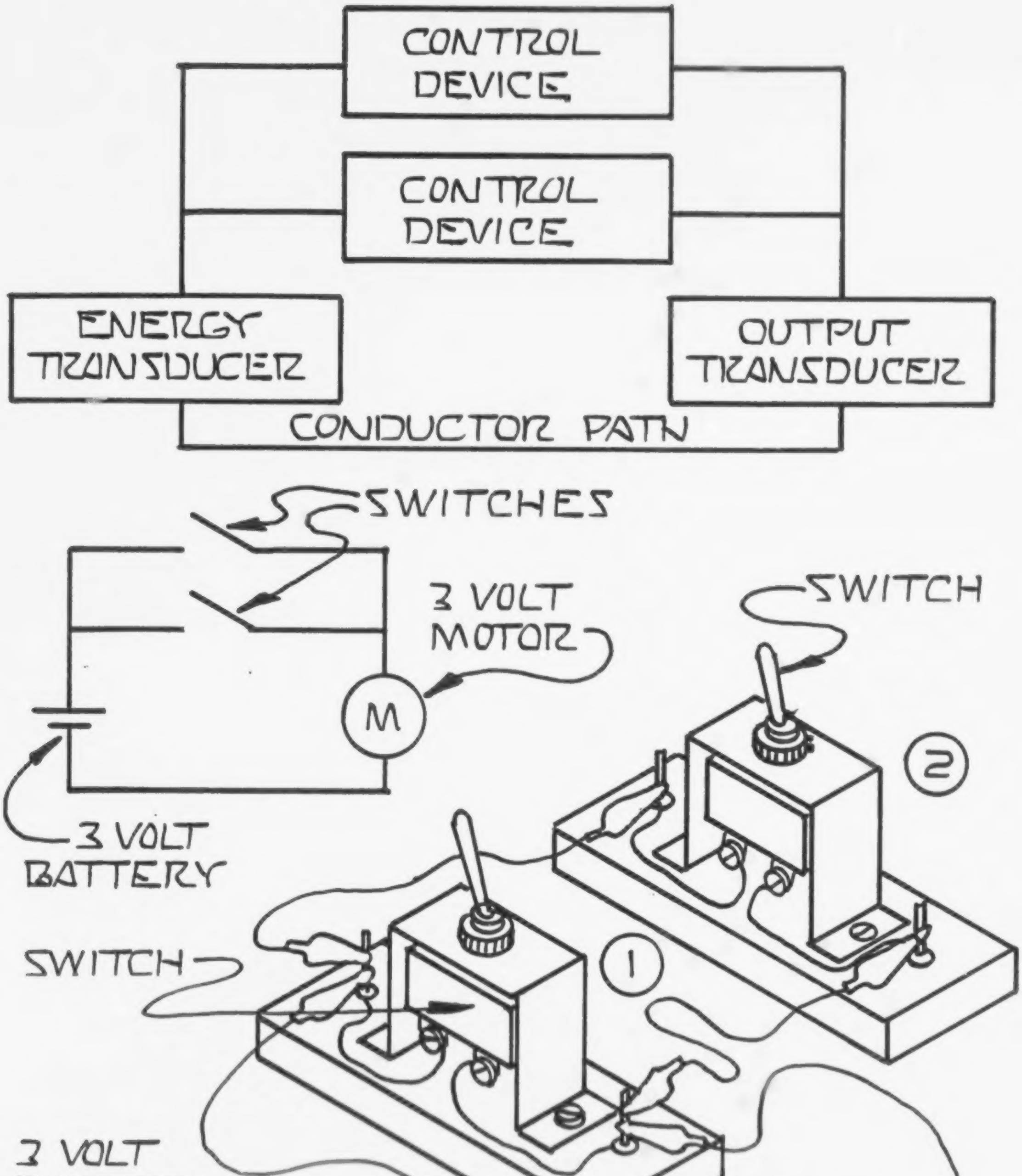

CONTROL DEVICE
CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH
SWITCHES
3 VOLT BATTERY
3 VOLT MOTOR
M
SWITCHES
①
②
3 VOLT MOTOR
3 VOLT BATTERY

FIGURE 4-4


CONTROL DEVICE
CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH
SWITCHES
3 VOLT MOTOR
M
3 VOLT BATTERY
SWITCH
②
①
SWITCH
3 VOLT BATTERY
3 VOLT MOTOR

OUTPUT TRANSDUCERS IN SERIES AND PARALLEL CIRCUITS

Christmas lights are often wired in series. Some of the light fixtures in our home are wired in parallel. Each circuit has different voltage and currentcharacteristics. During the following lab activity, you will make and test two circuits. One circuit will have two output transducers connected in series. The second circuit will have two output transducers connected in parallel.

Making and Testing a Series Circuit:

1. To perform the following lab activity, you will need:

    * 1 6 volt energy transducer
    * 2 lamp assemblies
    * 1 switch
    * 5 jumper leads
    * 1 volt meter
    * 1 milliamp meter

2. Using the parts listed above, make the circuit illustrated in Figure 4-5.

3. When your circuit is complete, make sure it works. Both lamps should light when the switch is closed. If the lamps do not light, check all your connections. If it still does not work, ask your teacher for assistance.

4. Measure the voltage drop across output transducer number one with a volt meter. Touch the positive test lead to the positive terminal on the output transducer. Touch the negative test lead to the negative terminal on the output transducer. Turn the switch on, read the meter, and record the voltage in the space below.

    __________volts

5. Measure the voltage drop across output transducer number two with a volt meter. Touch the positive test lead to the positive terminal on the output transducer. Touch the negative test lead to the negative terminal on the output transducer. Turn the switch on, read the meter, and record the voltage in the space below.

    __________ volts

6. Add the voltage drops measured across the two output transducers together.

    Voltage drop 1 + voltage drop 2 = voltage rise

    ______ volts + ______ volts = ______ total volts

7. Measure the voltage across the energy transducers with a volt meter. Touch the positive test lead to the positive terminal on the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Read the meter and record the voltage in the space below.

__________ volts

8. The voltage rise figured in step number 6 is _____ the voltage rise measured in step 7. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

9. Measure the current between the energy transducer and the output transducer with a milliamp meter. Connect the positive test lead to the negative terminal on the output transducer. Connect the negative test lead to the jumper wire going to the negative terminal on the energy transducers. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

10. Measure the current between the two output transducers with a milliamp meter. Connect the positive test lead to the negative terminal on output transducer number one. Connect the negative test lead to the positive terminal on output transducer number two. Make sure the milliamp meter is between the two output transducers. turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

11. Current is the same no matter where it is measured in a series circuit. Circle the best answer.

   A. true
   B. false

Making and Testing a Parallel Circuit:

1. Take your series circuit apart and make the circuit illustrated in Figure 4-6.

2. When your circuit is complete, make sure it works. Both lamps should light when the switch is closed. If the lamps do not light, check all your connections. If it still does not work, ask your teacher for assistance.

3. Measure the voltage drop across the first output transducer in the circuit with a volt meter. Touch the positive test lead to the positive terminal on the output transducer. Touch the negative test lead to the negative terminal on the output transducer. Turn the switch on, read the meter and record the voltage in the space below.

   __________ volts

4. Measure the voltage drop across the second output transducer in the circuit with a volt meter. Touch the positive test lead to the positive terminal on the output transducer. touch the negative test lead to the negative terminal on the output transducer. Turn the switch on, read the meter and record the voltage in the space below.

   __________ volts

5. Measure the voltage rise across the energy transducer with a volt meter. Touch the positive test lead to the positive terminal on the energy transducer. Touch the negative test lead to the negative terminal on the energy transducer. Turn the switch on, read the meter and record the voltage in the space below.

   __________ volts

6. Voltage is the same no matter where it is measured in a parallel circuit. Circle the best answer.

   A. true
   B. false

7. Measure the current flowing through output transducer one. Connect the positive test lead to the negative terminal on output transducer number one. Connect the negative test lead to the jumper wire going to the negative terminal on the energy transducer. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

8. Measure the current flowing through output transducer two. Connect the positive test lead to the negative terminal on output transducer number one. Connect the negative test lead to the jumper wire going to the negative terminal on the energy transducer. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

9. Add the two output transducer branch circuits together.

branch current 1 + branch current 2 = total current

______ milliamps + ______ milliamps = ______ milliamps

10. Measure the current between the energy transducers and the output transducer with a milliamp meter. Connect the positive test lead to the jumper wire coming from the negative terminal on the output transducer. Connect the negative test lead to the jumper wire going to the negative terminal on the second energy transducer. Turn the switch on, read the meter, and record the current in the space below.

__________ milliamps

11. The sum of the branch currents (figured in step #9) is _____ the current measured in step #10. Circle the best answer.

   A. greater than
   B. less than
   C. equal to

FIGURE 4-5

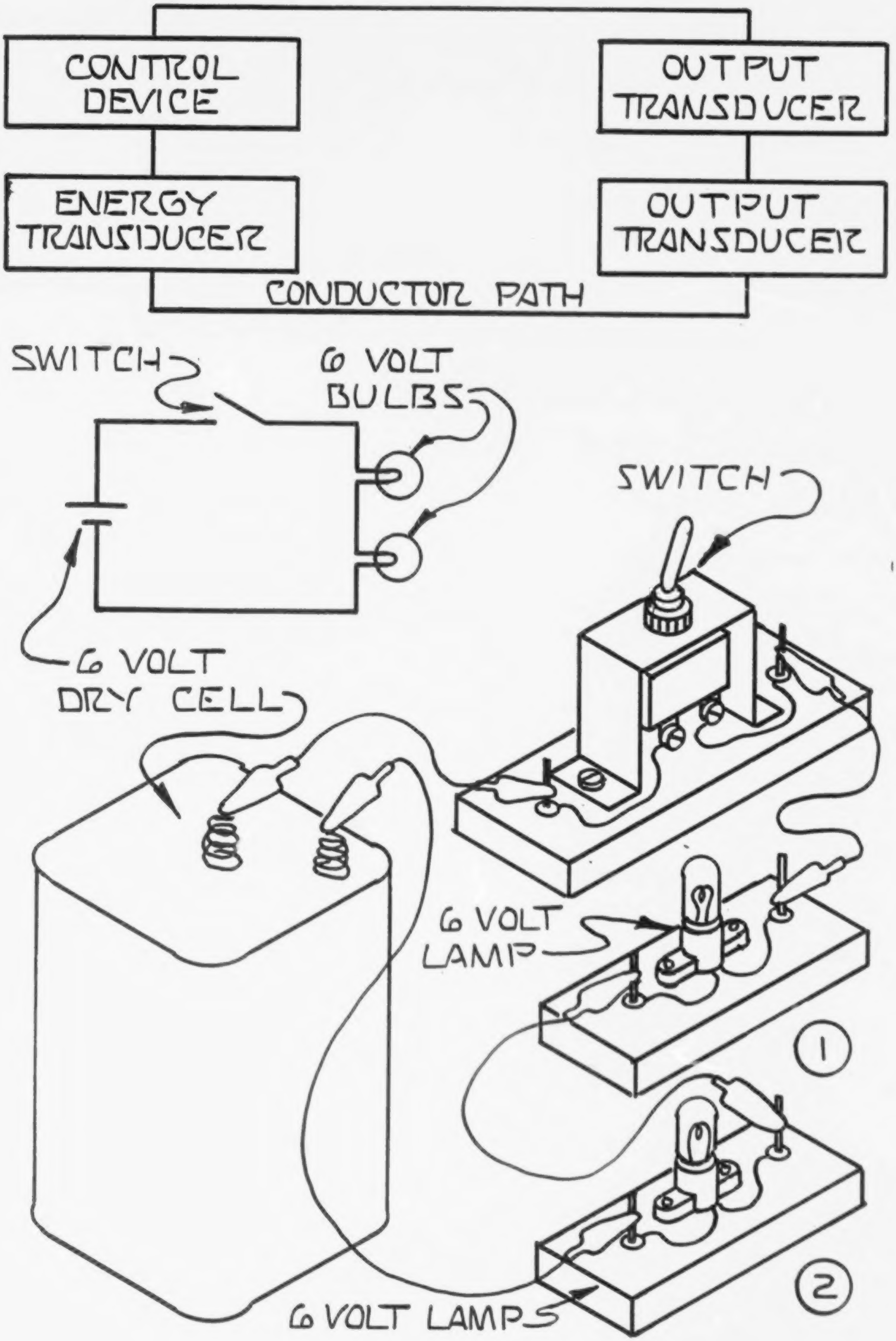
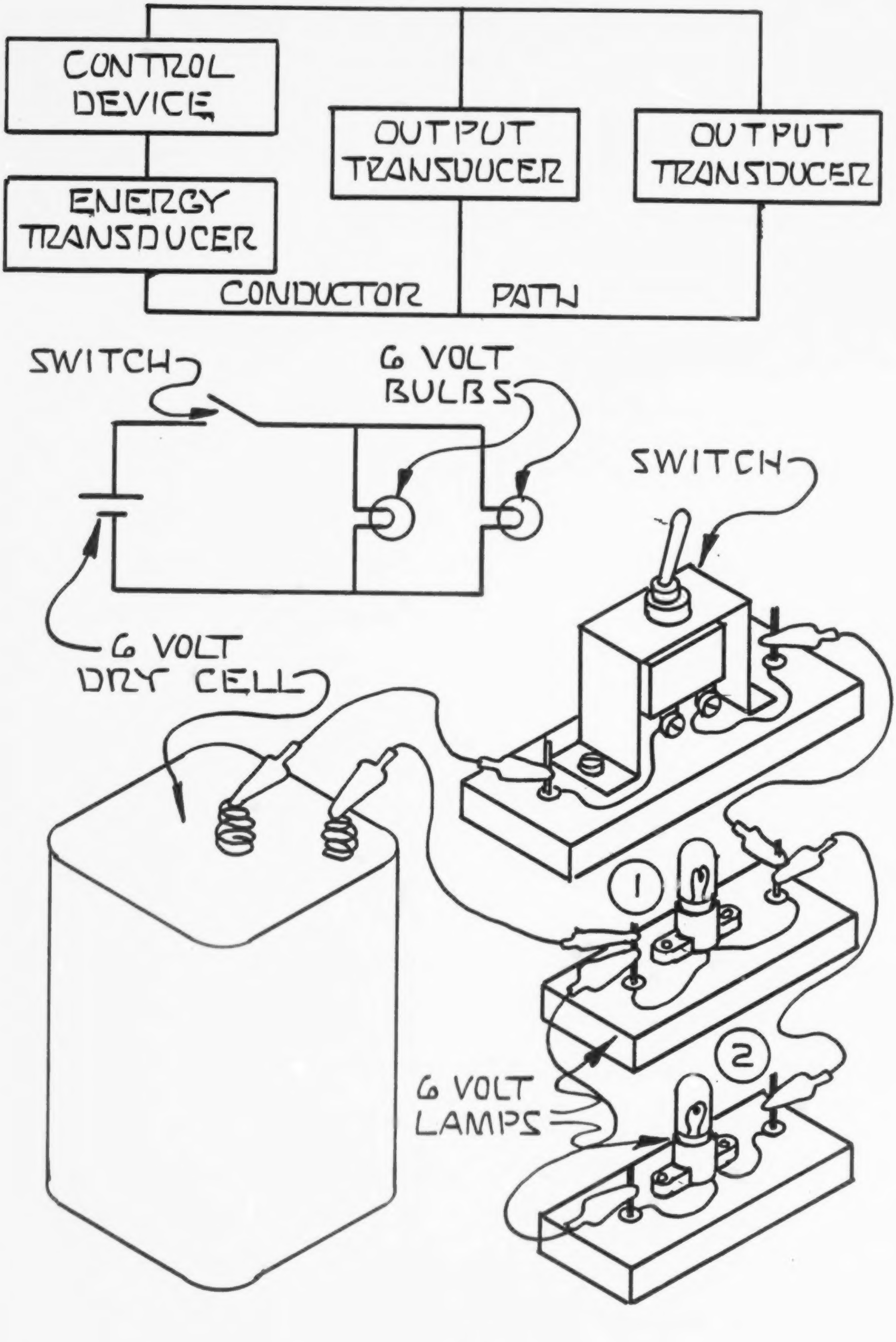

CONTROL DEVICE
OUTPUT TRANSDUCER
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH
SWITCH
6 VOLT BULBS
6 VOLT DRY CELL
SWITCH
6 VOLT LAMP
①
②
6 VOLT LAMPS

FIGURE 4-6


CONTROL DEVICE
ENERGY TRANSDUCER
OUTPUT TRANSDUCER
OUTPUT TRANSDUCER
CONDUCTOR PATH
SWITCH
6 VOLT BULBS
6 VOLT DRY CELL
SWITCH
1
2
6 VOLT LAMPS

Unit: Exploring Electricity/Electronics — Lesson 5: Introduction to Electronics

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for electronics. -describe how semiconductor devices are made. -identify three examples of semiconductor devices. -identify the two basic types of electronic systems.	A. Introduction to electronics 1. Electronics is controlling voltage and current through semiconductor devices. 2. Semiconductors are made of silicon that has been doped with impurities to change its electrical characteristics. 3. Basic semiconductor devices a. diodes b. transistors c. integrated circuits 4. Types of electronic systems a. digital b. analog 5. Digital control systems regulate voltage in the form of on and off pulses. 6. Analog systems regulate voltage and current in the form of smooth and continuous changes.	A. Teacher Guided Discussion 1. Ask students to describe what they think of when they hear the word electronics. 2. Using OT #5-1, discuss a definition for electronics. 3. Using OT #5-2, discuss a definition for semiconductors. 4. Using OT #5-3, discuss the three basic types of semiconductor devices. 5. Using OT #5-4, introduce students to the two basic types of electronic systems. 6. Using OT #5-5, explain how digital systems control voltage and current. 7. Using OT #5-6, explain how analog systems control voltage and current.	

B. Following a demonstration, in a lab activity, students will be able to:
- -use schematic drawings and common electronic components to build a working burglar alarm.
- -complete statements describing how the alarm works.

B. Making and analyzing an electronic alarm.
1. Making the alarm
    a. reading a schematic
    b. making the circuit
    c. testing the circuit
2. Analyzing the alarm
    a. describing current flow when the alarm is on
    b. describing the current needed to trip the alarm
    c. describing current flow when the alarm is tripped

B. Learning Activity
1. Explain the need for an electronic control system in a burglar alarm circuit.
2. Explain how to use the schematic drawings to build a working burglar alarm. Emphasize how to handle electronic components and make good connections.
3. Provide students with #5-1 and the tools and materials needed to make burglar alarms.
4. Have students make the burglar alarms.
5. Circulate around the room and provide individual instruction as needed.
6. When students have finished their burglar alarms, demonstrate how to measure current in their alarm circuit. Explain how to complete the circuit analysis portion of the lab sheet.
7. Have students complete the lab activity.
8. Collect and evaluate your students' burglar alarms and lab sheets.

INTRODUCTION TO ELECTRONICS

Preparation Hints:

1. Review the materials provided, duplicate HO #5-1, and prepare the transparancies needed to present this lesson.

2. During the lab activity, your students will be making a simple electronic burglar alarm. Prior to implementing this lesson, you will need to collect and organize the electronic components listed on HO #5-1. The technique used to build the circuit requires each component to have leads that can be wrapped around screws. You will probably need to solder short wire leads on the variable resisters, slide switches, and possibly the relays. If you want students to do the soldering, you will need to prepare a lesson on soldering electronic components. To keep from losing small electrical components, you may want to put each burglar alarm kit in a plastic bag.

3. In addition to the components listed on HO #5-1, your students will also need access to white glue, silicone glue, wire strippers, needle nosed pliers, screw drivers, and a drill equipped with a 1/8" drill bit. To save time, you may want students to use a drill press.

4. Prior to implementing this lesson, consider using the materials provided to make your own burglar alarm. Making and testing an alarm will help you anticipate problems and develop strategies for assuring student success. In addition, you can use your working example to demonstrate how to build and test the circuit.

Content Presentation Hints:

1. Show students a variety of semiconductor devices. Your examples could include things like diodes, LED's, transistors, and integrated circuits.

2. Ask your local electronics service centers to save you defective circuit boards from a variety of electronic devices. Try to obtain circuit boards from old electronic devices, as well as new ones. Show students what electronic control systems look like by passing the circuit boards around the class. Ask students to identify the differences between the old and new circuit boards. New boards typically contain more integrated circuits while older ones contain more transisters and other discrete electronic components.

3. Consider showing a film or video tape on electronics, semiconductors, integrated circuits, or microelectronics.

4. To show students how a transistor uses a small force to control a large force, consider building the circuit illustrated in Figure 5-1.

Learning Activity Hints:

1. If you or your students cannot afford to build burglar alarms as take-home projects, consider mounting the components needed on their own individual fixtures. Have teams of students build the alarms using jumper leads. You will need to modify the lab sheet prior to implementing the lesson.

2. When showing students how to build their alarm, demonstrate how to bend the leads on the transistor so they will loop around the screws. Explain how to identify the emitter, base, and collector leads on a transister. Emphasize the importance of installing the transister in the circuit correctly. You may want to purchase a few extra transisters in the event students install them incorrectly.

3. Explain how to identify the leads on a relay. Demonstrate how to connect each lead into the burglar alarm circuit. Make sure students do not wrap the leads so tight that they break or distort the relay when the screws are tightened.

4. Consider making a bracket that can be fastened to the burglar alarm so that it can be installed around a door knob. Refer to Figure 5-2 for an example. By installing a hanger on the alarm and using double faced tape on the magnetic switches, the alarm can be installed onto most any door.

OT #5-1

Electronics is controlling voltage and current through semiconductor devices.

OT #5-2

Semiconductors are made of silicon that has been doped with impurities to change its electrical characteristics.

OT #5-3

Basic semiconductor devices:

- * diodes
- * transistors
- * integrated circuits

OT #5-4

Types of electronic systems:

- * digital
- * analog

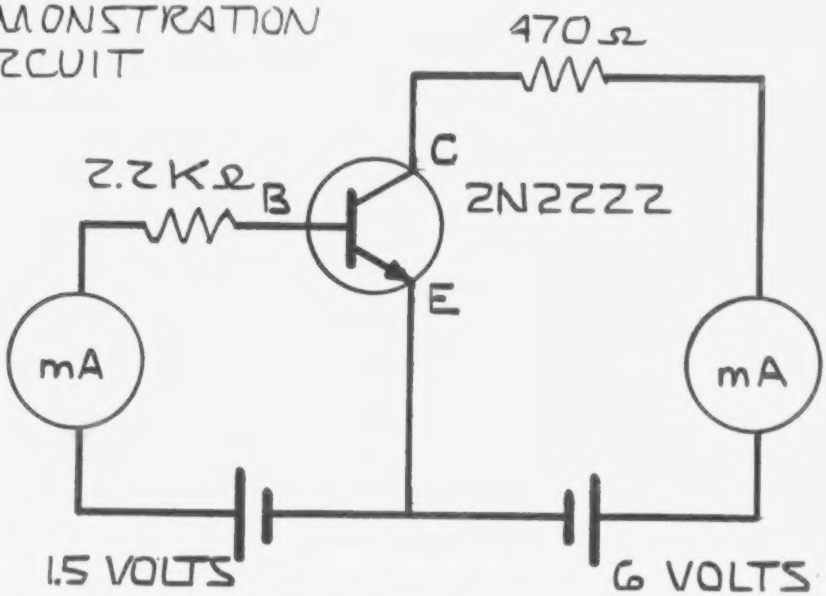
OT #5-5

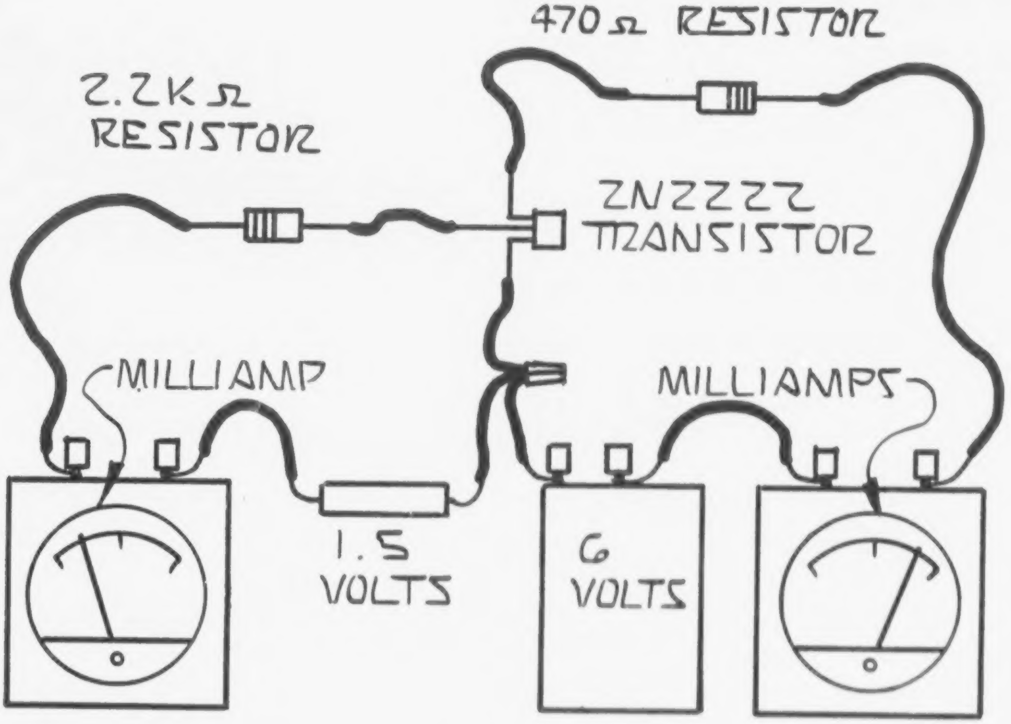
Digital control systems regulate voltage in the form of on and off pulses.

OT #5-6

Analog systems regulate voltage and current in the form of smooth and continuous changes.

FIGURE 5-1.
TRANSISTOR
DEMONSTRATION
CIRCUIT





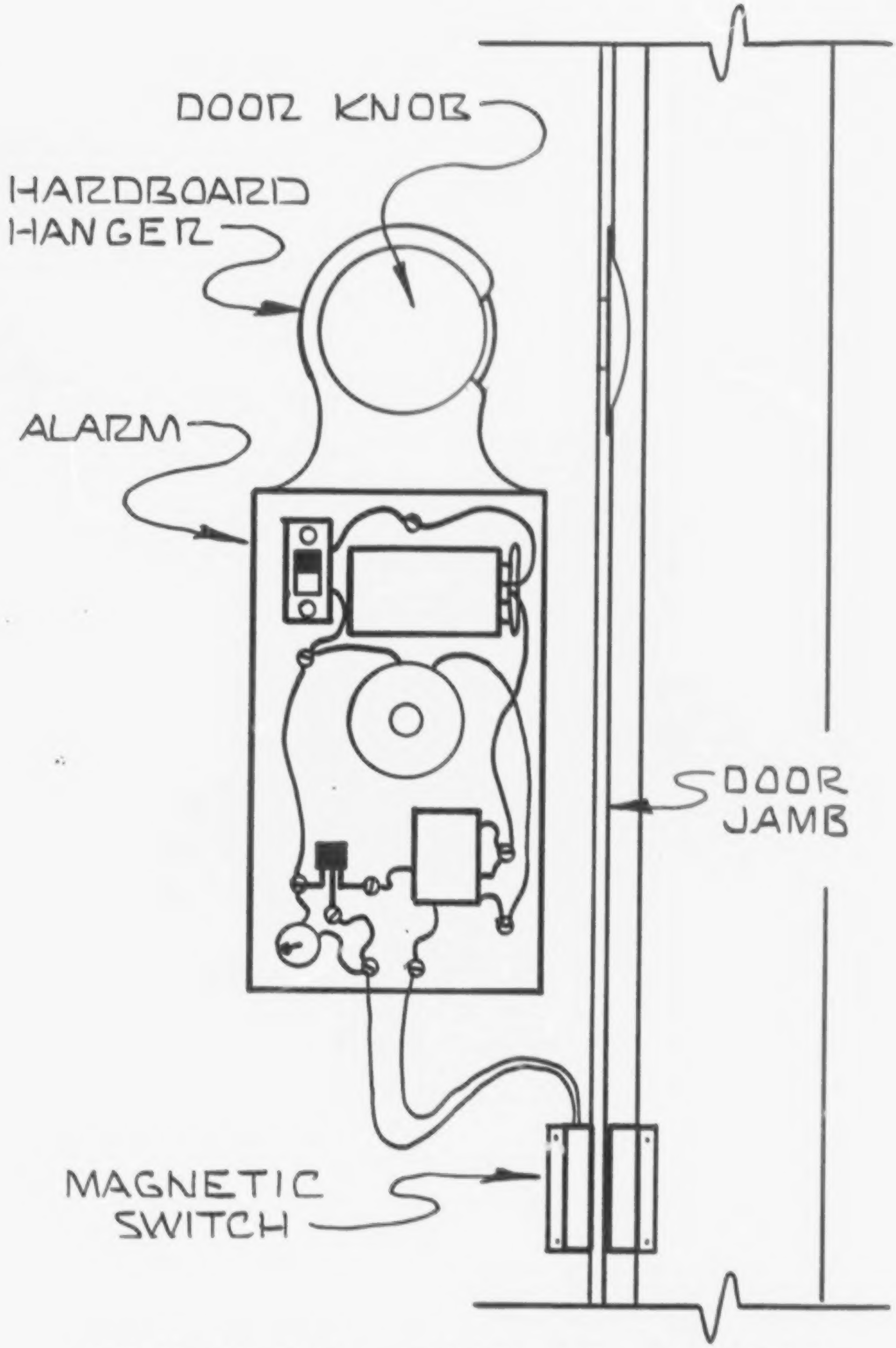


FIGURE 5-2. BURGLAG ALARM INSTALLATION

INTRODUCTION TO ELECTRONICS

Discussion:

Electricity is the flow of electrons through a conductor. We use electrical energy in moving electrons to perform work. Controlling electrical energy with semiconductor devices is called electronics. Semiconductors are materials that are not good conductors or good insulators. The most commonly used semiconductor material is silicon. Being the primary ingredient of sand, it is one of the most common elements found on earth.

Pure silicon is basically an insulator and is not very useful. However, by carefully adding impurities to the silicon, it can act like a conductor. This contamination process is called doping. Impurities like boron, arsenic, aluminum, and phosphorus are added to give it excess electrons or deficiency of electrons. Silicon with extra electrons is called N-type (negative) silicon. Silicon with a deficiency of electrons is called P-type (positive) silicon. Manufacturers of semiconductor devices join pieces of N-type and P-type silicon to make components like diodes, LED's, transistors, and integrated circuits.

Diodes are semiconductor devices that act like a one-way value in a circuit. They allow current to flow in one direction but not the other. LED is an acronym for Light Emitting Diode. They are a special kind of diode because they are made of semiconductor materials that convert electrical energy into radiant energy. LED's are often used for the display on many calculators.

Transistors use three layers of silicon to control current and voltage in a circuit. Each layer is connected to a lead. The current flowing through the two outside leads is controlled by a small voltage applied to the center lead. Small changes in the amount of voltage applied to the center lead create large changes in the current flowing through the other two leads. Transistors, in a way, work like a water faucet. The water under pressure in your water pipes wants to flow. When you apply a small force to the faucet handle, water begins to flow. If you apply a little more force and turn the handle, even more water flows through the faucet. Depending on the circuit, transistors can act like a switch or an amplifier. In both cases, a small force is used to control a large force. Before the transistor, electronic devices were large and very unreliable. Radios and television had to warm up before they would work, they were not portable, and they needed to be serviced on a regular basis. Thanks to the transistor, electronic devices are much smaller and more reliable even though they are more complex.

Semiconductor manufacturers discovered they could use silicon to make more than just diodes and transistors. By adding different impurities to silicon, they could make components like resistors and capacitors. Best of all, they could put more than one component on a single piece of silicon. They have developed ways to put a whole circuit on a silicon chip that measures about 3/16 of an inch square. When a whole circuit is put on a chip, it is called an integrated circuit. Today, engineers can put a circuit containing more than one hundred thousand transistors on a single chip. Advances in integrated circuit technology have revolutionized electronics. These advances have created a new type of electronics often referred to as microelectronics. Microelectronics is what makes hand-held calculators, stereos, two-way radios, and television sets possible. In addition, microelectronics has revolutionized the computer industry. Thanks to inexpensive integrated circuits, people can purchase portable personal computers that fit inside a brief case.

There are two major types of electronic control systems, digital and analog. Analog control systems regulate voltage and current in the form of smooth and continuous changes. On a graph, these changes would look like waves. Regulating the amount of light in a room by slowly adjusting a dimmer switch is an example of analog control.

Digital control systems regulate voltage and current in the form of on and off pulses. On a graph, these changes would look like steps. Regulating the amount of light in a room by turning a switch on or off is an example of digital control.

Controlling electrical energy with semiconductor devices is called electronics. Examples of semiconductor devices include diodes, transistors, and integrated circuits. They are made of silicon that has been dopped with impurities to change its electrical characteristics. There are two basic types of electronic systems, digital and analog. Digital systems control voltage and current with on and off impulses. Analog systems control voltage and current by changing their levels smoothly.

Learning Activity:

Simple control devices have a lot of limitations in an electrical system. They can start and stop current by opening and closing a circuit. They can regulate current by changing the resistance in a circuit. However, they can not process, amplify, or modify an electrical signal. For example, a simple burglar alarm consisting of a battery, magnetic switch, and piezo buzzer will sound if the magnet is removed. However, the buzzer can be shut off by simply replacing the magnet. A real burglar alarm would continue to sound even if the magnet is replaced. It would use an electronic control system to disconnect the magnet switch after it has been tripped and complete the circuit between the energy transducer and the output transducer.

During this lab activity, you will make and test a burglar alarm. The alarm will use a transistor and a complex circuit to control voltage and current. When you have finished the system, the alarm will sound when the switch is opened and will continue to sound until the power is disconnected.

Making a Burglar Alarm:

1. To make a simple electronic burglar alarm, you will need the following materials:

   * 1 9 volt battery
   * 1 9 volt battery snap connector with leads
   * 1 100k variable resistor (potentiometer)
   * 1 2N2222 transistor
   * 1 heavy-duty SPST slide switch
   * 1 SPDT, 6-9 volt, 500 ohm relay
   * 1 piezo electric buzzer
   * 2 1" number 8 pan head screws
   * 2 pieces of plastic hose 3/4" long
   * 12 1/2" number 8 pan head screws
   * 2 pieces of wire 12" long
   * 2 pieces of wire 3" long
   * 1 piece of wood 6" long, 3 1/2" wide, and 3/4" thick
   * 1 magnetic burglar alarm switch

2. Spread a thin film of glue on the top of your block of wood. Locate your schematic on the block of wood so the border of the drawing lines up with the edges of the wood. Smooth the air bubbles out from underneath the schematic and allow it to dry for a few minutes. Cut the excess paper around the edges of your wood block.

3. Using a 1/8" bit, drill holes about 1/2" deep at each of the locations shown on the schematic. Drive a pan head screw about half way into each hole.

4. Find the location for the transistor on the schematic. Bend the leads VERY carefully so they will touch each screw. Place the transistor in its location with the flat side facing down. The collector lead should be touching the screw labeled C. The base lead should be touching the screw labeled B. Lastly, the emitter lead should be touching the screw labeled E. Carefully loop each lead clockwise around their screws.

5. Find the location for the variable resistor on the schematic. Place the resistor in its location with the dial face up. Wrap one lead clockwise around the screw labeled C. Wrap the other lead clockwise around the screw labeled T1.

6. Using one of the 3" long wires, install a conductor between the screw labeled E and the screw labeled T1.

7. Find the location for the slide switch on the schematic. Use the one inch screws and the spacers to mount the switch in its location. Wrap one lead clockwise around the screw labeled S1. Wrap the other lead clockwise around the screw labeled S2.

8. Find the location for the relay on the schematic. Wrap the normally open contact lead clockwise around the screw labeled NO. Wrap the normally closed contact lead clockwise around the screw labeled T2. Wrap the movable contact lead clockwise around the screw labeled MC. Wrap one coil lead clockwise around the screws labeled MC. Wrap the other coil lead clockwise around the screw labeled E. Place a bead of silicone glue under the relay. Push the relay into the glue and allow it to dry.

9. Using two screws, mount the piezo electric buzzer in its location. Wrap the positive lead clockwise around the screw labeled S1. Wrap the negative lead clockwise around the screw labeled NO.

10. Using one of the 3" long wires, install a conductor between the screw labeled S1 and the screw labeled C.

11. Find the location for the nine volt battery snap connector. Loop the red lead clockwise around the screw labeled S2. You may need to strip more insulation off the wire so it will wrap all the way around the screw. Loop the black lead clockwise around the screw labeled NO.

12. Strip about 1/2" of insulation off each end of 12" long wires. Loop one end of one wire clockwise around the screw labeled T1. Loop one end of the other wire clockwise around the screw labeled T2. Connect the other two ends to the magnetic switch.

13. Carefully tighten each screw. Do not over tighten the screws. You do not want to distort the leads or drive the connections into the wood.

14. Fasten the snap connector to your nine volt battery. Apply a 1" bead of silicone glue where the battery will be located. Push the battery into the glue and allow to dry.

15. Test your burglar alarm by moving the slide switch to its on position. Move the magnet away from the switch. The alarm should sound. If it does not, adjust the variable resistor until you hear the relay click and the piezo buzzer sounds. If your alarm still does not work, check your switch, battery, and connections. As a last resort, ask your teacher for assistance.

Analyzing the Circuit:

1. Now that your burglar alarm is assembled, lets figure out how it works. When your alarm is turned on, current flows from the battery through the normally closed relay contacts, the magnetic switch, the variable resistor, the slide switch, and back to the battery (see Figure 5-3). With the slide switch in the off position and the magnetic switch closed, measure the current between S1 and S2. Touch the positive test lead to the screw labeled S1. Touch the negative lead to the screw labeled S2. Read the meter and record the voltage in the space below.

   ___________ milliamps

2. When the magnet is moved away from the magnetic switch, the switch opens and the current path described above is broken. The current from the battery must find a new path back to the battery. Therefore, current flows from the battery through the relay coil, into the emitter lead of the transistor, out the base lead of the transistor, through the variable resistor, through the slide switch, and back to the battery (see Figure 5-4). Will this new current path cause the alarm to sound? Do not worry if you do not know the answer. Circle your best guess.

   A. yes
   B. no

3. The answer to the question above is yes and no. Technically, the new current path does not drive the piezo buzzer. It does trigger another circuit that will drive the piezo buzzer. The current flowing through the new circuit is not strong enough to close the relay. However, the current flowing through the emitter to the base of the transistor is strong enough to allow current to flow through the emitter to the collector (see Figure 5-5). The current flowing through the emitter to the base is the small force controlling the large force. The large force is the current flowing through the emitter to the collector. It is strong enough to create a magnetic field around the relay coil and move the contact. Let's test this idea. Remove the jumper lead between the screw labeled B and the screw labeled T1. Move the slide switch to the on position. Touch the positive test to the screw labeled T1. The alarm should sound. Read the meter and record the current in the space provided below.

   __________ milliamps

4. Move the slide switch to the off position. Reinstall the jumper lead between the screw labeled E and the screw labeled T1. Disconnect the relay lead wrapped around the screw labeled E. Measure the current between the relay lead and the screw labeled E. Move the slide switch to its on position. Touch the positive lead to the screw labeled E. Touch the negative test lead to the lead coming from the relay. The alarm should sound. Read the meter and record the current in the space below.

   __________ milliamps

5. The current flowing into the transistor's emitter is _____ the current flowing through its base. Circle best answer.

   A greater than
   B. equal to
   C. less than

6. Move the slide switch to its off position and reinstall the relay lead around the screw labeled E.

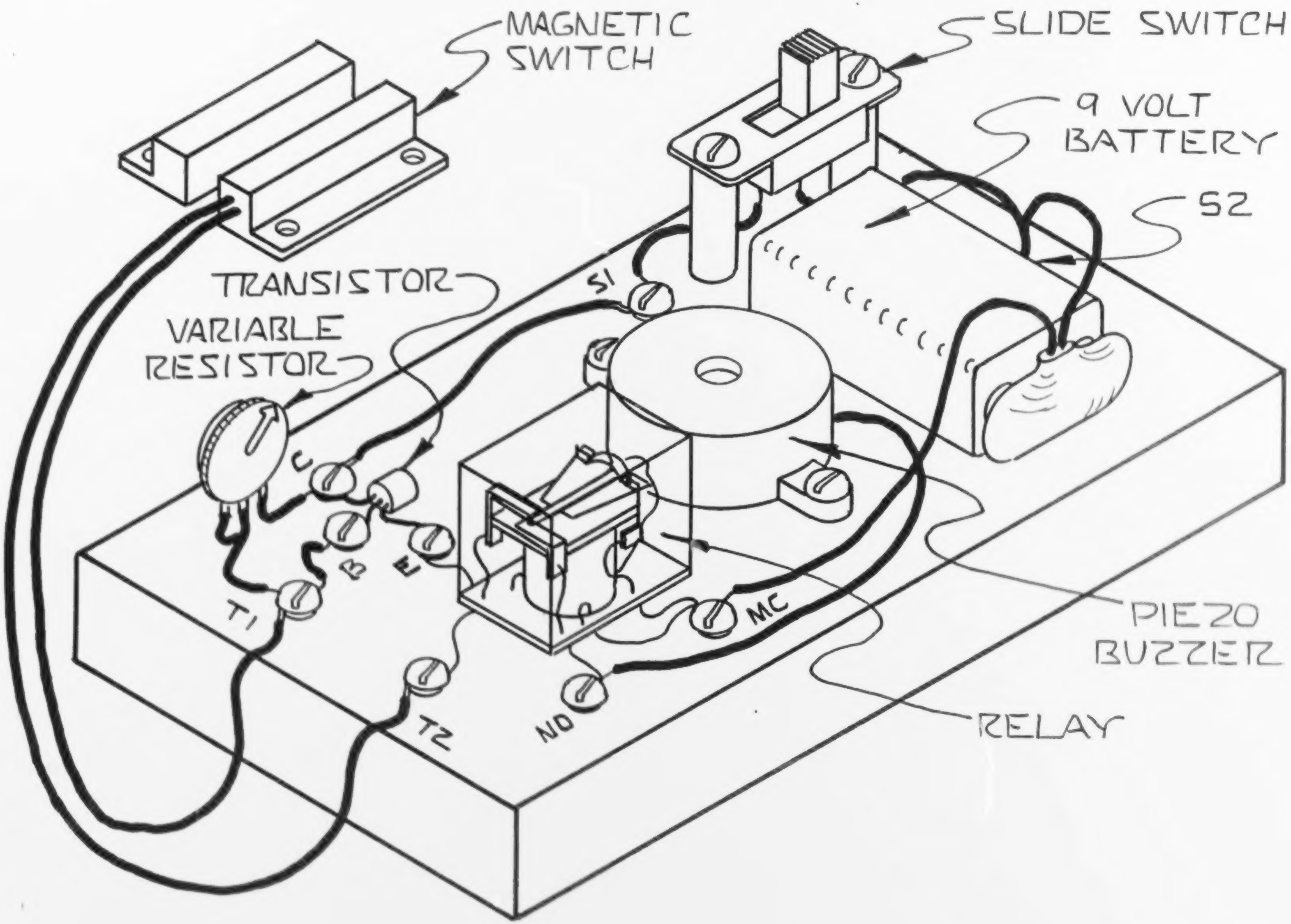
7. When the transistor triggers the relay, the movable contact disconnects the magnetic switch. In the process, it connects the battery to the piezo buzzer. Not only is current flowing through the relay and the transistor, current is now flowing through the relay to the piezo buzzer (see Figure 5-6). Needless to say, this current causes the piezo buzzer to sound. Measure the total current flowing when the alarm is tripped.

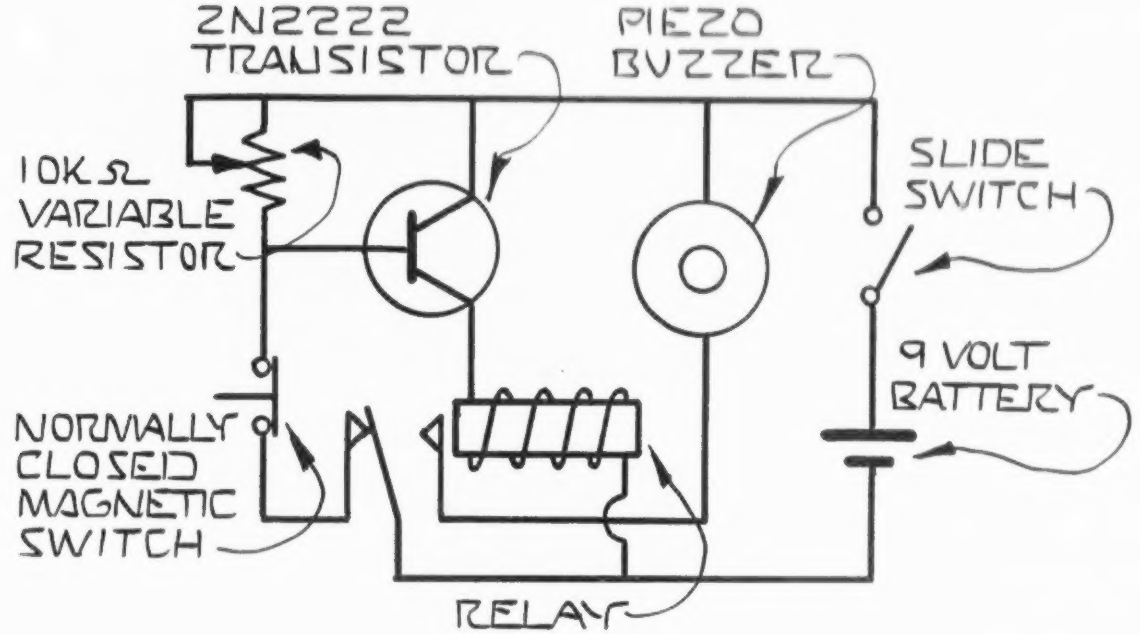
Make sure the magnet is touching the magnetic switch. With the slide switch in the off position and the magnetic switch closed, measure the current between S1 and S2. Touch the positive test lead to screw labeled S1. Touch the negative lead to the screw labeled S2. Move the magnet away from the magnet switch while watching the meter. Read the meter and record the voltage in the space below.

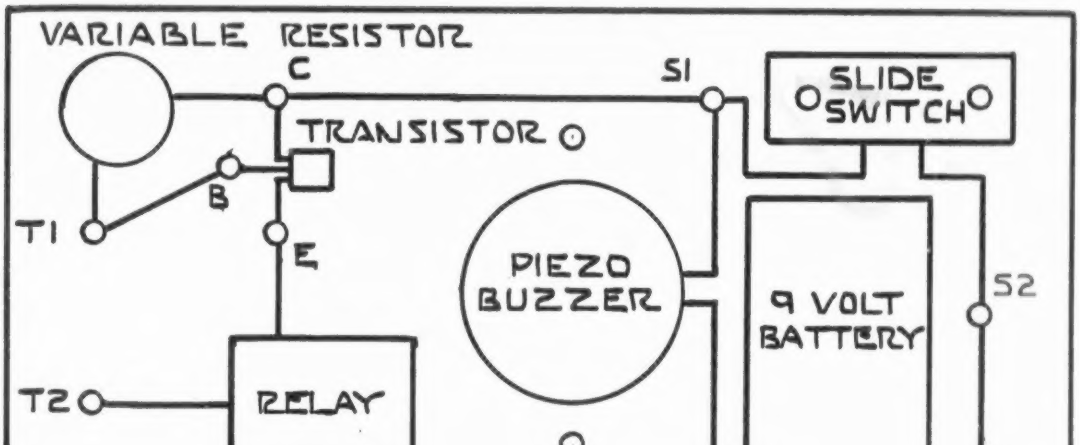
__________ milliamps

8. Total current in the circuit _____ when the alarm is tripped. Circle the best answer.

   A. decreases
   B. stays the same
   C. increases


MAGNETIC SWITCH
SLIDE SWITCH
9 VOLT BATTERY
S2
TRANSISTOR
VARIABLE RESISTOR
S1
C
B
E
T1
T2
NO
MC
PIEZO BUZZER
RELAY


2N2222 TRANSISTOR
PIEZO BUZZER
10K Ω VARIABLE RESISTOR
SLIDE SWITCH
9 VOLT BATTERY
NORMALLY CLOSED MAGNETIC SWITCH
RELAY


VARIABLE RESISTOR
C
S1
SLIDE SWITCH
TRANSISTOR
B
T1
E
PIEZO BUZZER
9 VOLT BATTERY
S2
T2
RELAY
NO
MC

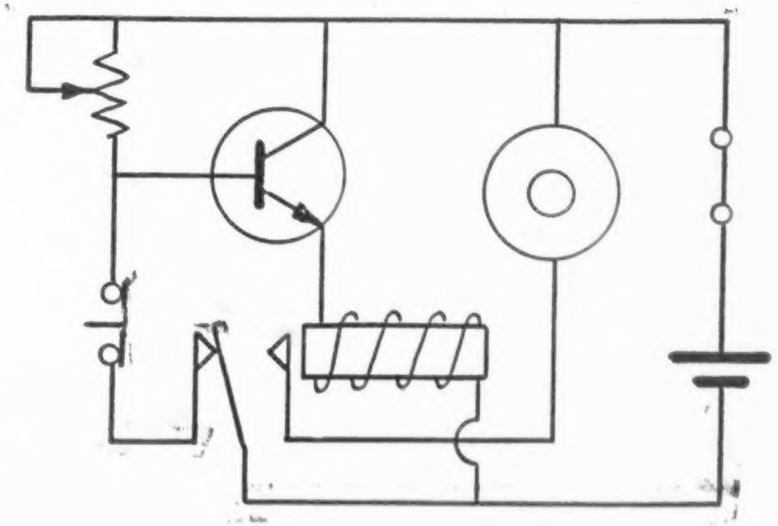


FIGURE S-3

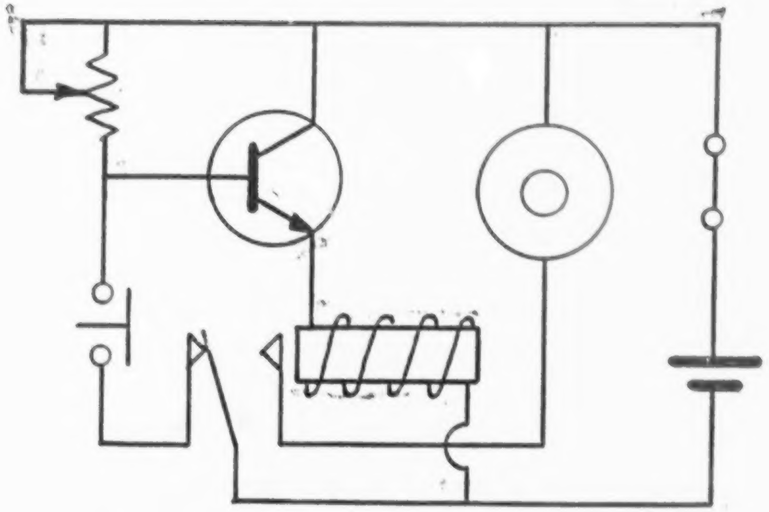


FIGURE S-4

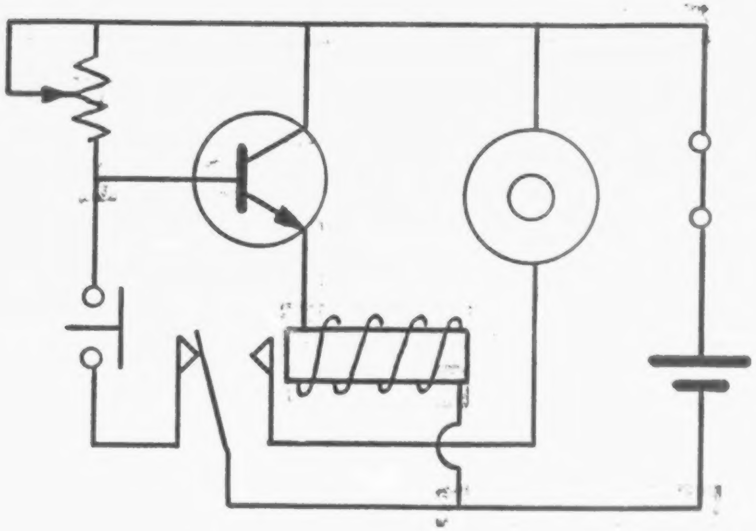


FIGURE 5-5

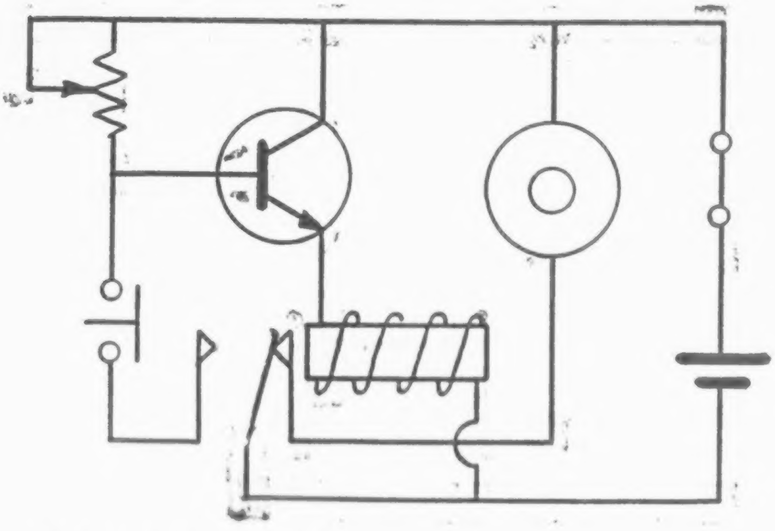


FIGURE 5-6

Unit: Exploring Electricity/Electronics

Lesson 6: Evaluation

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a review on a written objective test, students will be able to complete given concept statements regarding electricity and electronics with a minimum of 70% accuracy.	A. Review 1. Introduction to electricity. 2. Energy transducers 3. Output transducers and control devices 4. Series and parallel circuits 5. Introduction to electronics	A. Teacher Guided Review 1. Review the major concepts explored during the unit. 2. Provide students with the opportunity to ask questions before taking the test. 3. Provide each student with HO #6-1 and make sure each student has a pen or pencil. 4. Explain the directions for the test. 5. Have the students read the test and answer the questions provided. 6. Collect the tests and grade your students performance. 7. Provide students with feedback regarding their test performance as soon as possible.	

EXPLORING ELECTRICITY UNIT EXAM

Directions: Read each question carefully. In the blank provided, write the letter of the answer option which best completes or answers the question.

1. Which of the following atomic particles has a negative charge?

   A. protons
   B. electrons
   C. neutrons
   D. ions

2. According to the first law of electrostatics, like charges _____ each other.

   A. repel
   B. destroy
   C. attract
   D. neutralize

3. An excess of electrons at one terminal and a deficiency at another is called _____.

   A. electromotive force
   B. resistance
   C. current
   D. potential difference

4. The movement of free electrons in one direction is called _____.

   A. random drift
   B. voltage
   C. current
   D. resistance

5. Materials that contain a lot of free electrons are called _____.

   A. conductors
   B. nonconductors
   C. insulators
   D. semiconductors

6. The force that causes electrons to flow in one direction is called _____.

   A. current
   B. voltage
   C. EMF
   D. potential difference

7. Which of the following is a second generation energy source?

   A. chemical energy
   B. electrical energy
   C. thermal energy
   D. radiant energy

8. Photovoltaic cells convert _____ energy to electrical energy.

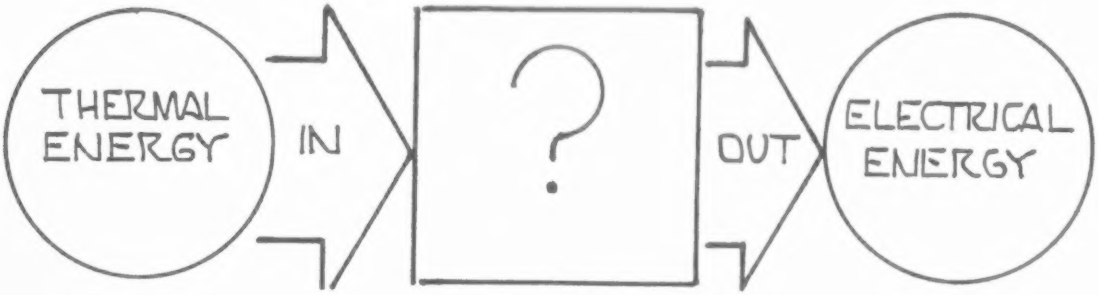
   A. radiant
   B. mechanical
   C. thermal
   D. chemical

9. Which of the following energy transducers uses two dissimilar metals and an electrolyte to convert energy?

   A. electromagnetic generators
   B. photovoltaics
   C. thermocouples
   D. batteries

10. Which of the following energy transducers will complete the flowchart illustrated below?

   A. thermocouples
   B. batteries
   C. photovoltaics
   D. electromagnetic generators



11. Which of the following elements of a circuit uses electrical energy to perform work?

   A. energy transducers
   B. output transducers
   C. control devices
   D. conductor paths

12. The basic element of a circuit that regulates electron flow is called a _____.

A. energy transducer
B. output transducer
C. control device
D. conductor path

13. Which of the following is an example of an output transducer?

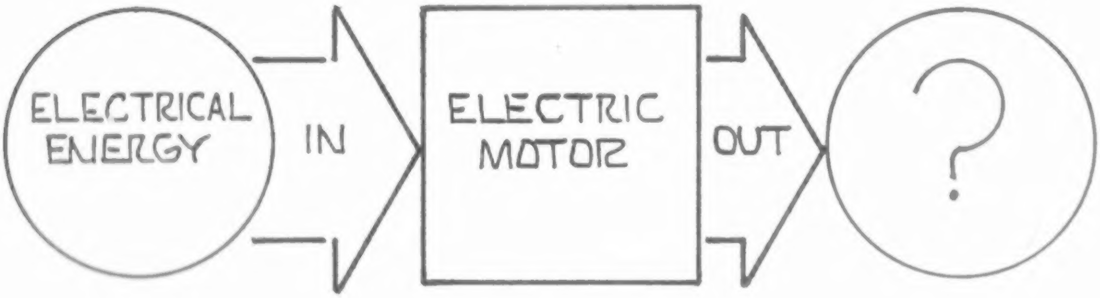
A. batteries
B. photocell
C. heating elements
D. thermostats

14. Which of the following control devices are mechanically actuated?

A. switches
B. thermostats
C. photocells
D. fuses

15. Which of the following forms of energy will complete the flowchart illustrated below?

A. radiant
B. thermal
C. mechanical
D. sound



16. A circuit containing only one conductor path is called a _____.

A. complex circuit
B. parallel circuit
C. series circuit
D. open circuit

17. Which of the following statements is true in a parallel circuit?

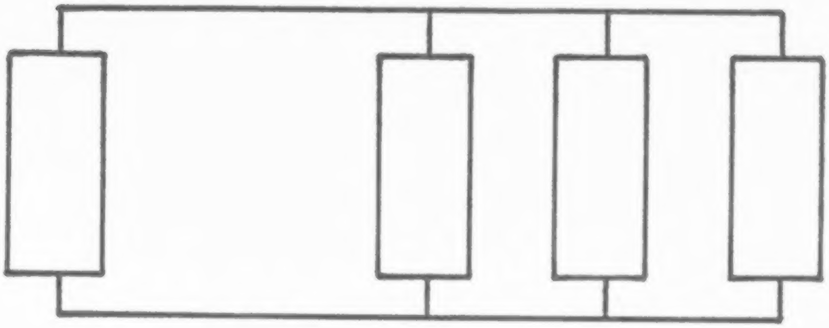
A. current is the same throughout the circuit
B. voltage is the same throughout the circuit
C. voltage divides across the output transducers
D. voltage rise equals the sum of the voltage drops

18. Circuits that use both series and parallel conductor paths are called _____?

A. complex circuits
B. compound circuits
C. complicated circuits
D. integrated circuits

19. The circuit illustrated below is an example of a _____.

A. parallel circuit
B. series circuit
C. complex circuit
D. integrated circuit



20. Current is measured in _____.

A. ohms
B. amperes
C. watts
D. volts

21. Which of the following materials is an insulator?

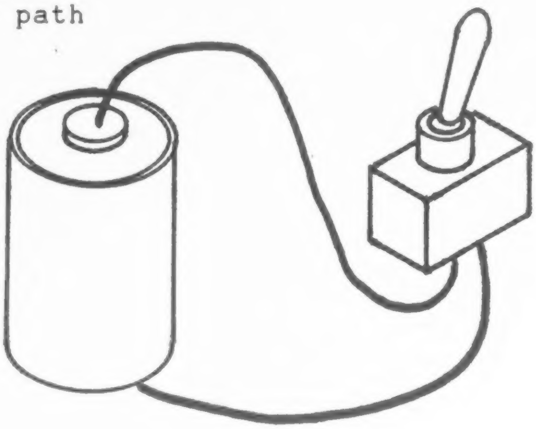
A. plastic
B. water
C. aluminum
D. copper

22. Continuity testers are used to _____.

A. check the conductor path
B. measure current flow
C. measure potential difference
D. measure electromotive force

23. To be a complete circuit, the schematic illustrated below needs a _____.

A. output transducer
B. energy transducer
C. control device
D. conductor path



24. Electronic control systems that regulate voltage and current in the form of on and off pulses are called _____.

A. pulse systems
B. digital systems
C. analog systems
D. integrated systems

25. Which of the following semiconductor devices contains a complete circuit on a single silicon chip?

A. diodes
B. transistors
C. photovoltaics
D. integrated circuits

26. Which of the following semiconductor devices uses a small force to control a large force?

A. diodes
B. LED's
C. transistors
D. integrated circuits

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